

ON 4 MAY 1982, SHEFFIELD – a British destroyer serving in the South Atlantic – suffered a direct hit. Sometime in the late afternoon, her radar system had detected an impending enemy attack. Her captain barely had time to shout, 'Take cover' as the missile – a deadly AM39 Exocet – hit the ship, ripping a hole in her side.

The effect of the impact was overwhelming. Twenty crew members were killed instantly, and the resulting explosion cut out all lighting and communications systems. Within 20 seconds, there was a roaring mass of flames and clouds of black smoke. Within minutes, HMS Sheffield was devastated.



Sea Skimmers

The loss of *Sheffield* marked a turning-point in the history of naval warfare; the use of Exocet heralded the beginning of a new age in sea weaponry.

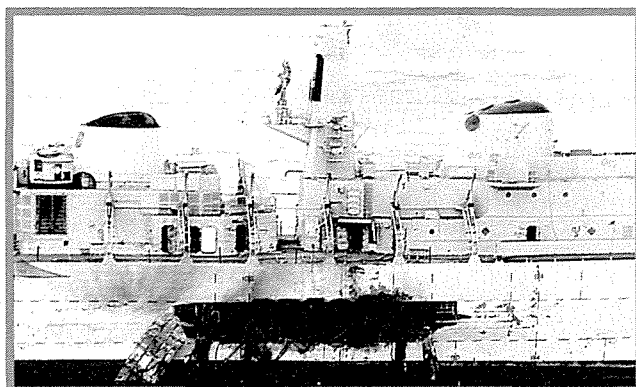
WEAPONS

AT

SEA

Before 1982, anti-ship attack consisted of high-flying missiles which were tracked by radar and shot down like an aeroplane. These have largely been superseded by a new breed of missiles called Sea Skimmers. Guided by radar, their advantages are enormous. Instead of approaching the target from overhead, the missile flies close to the sea surface to avoid detection by radar. Known as a 'fire and forget' missile – once launched, the operator can forget about it – it will find its own way to its target.

Exocet measures 5.2 metres in



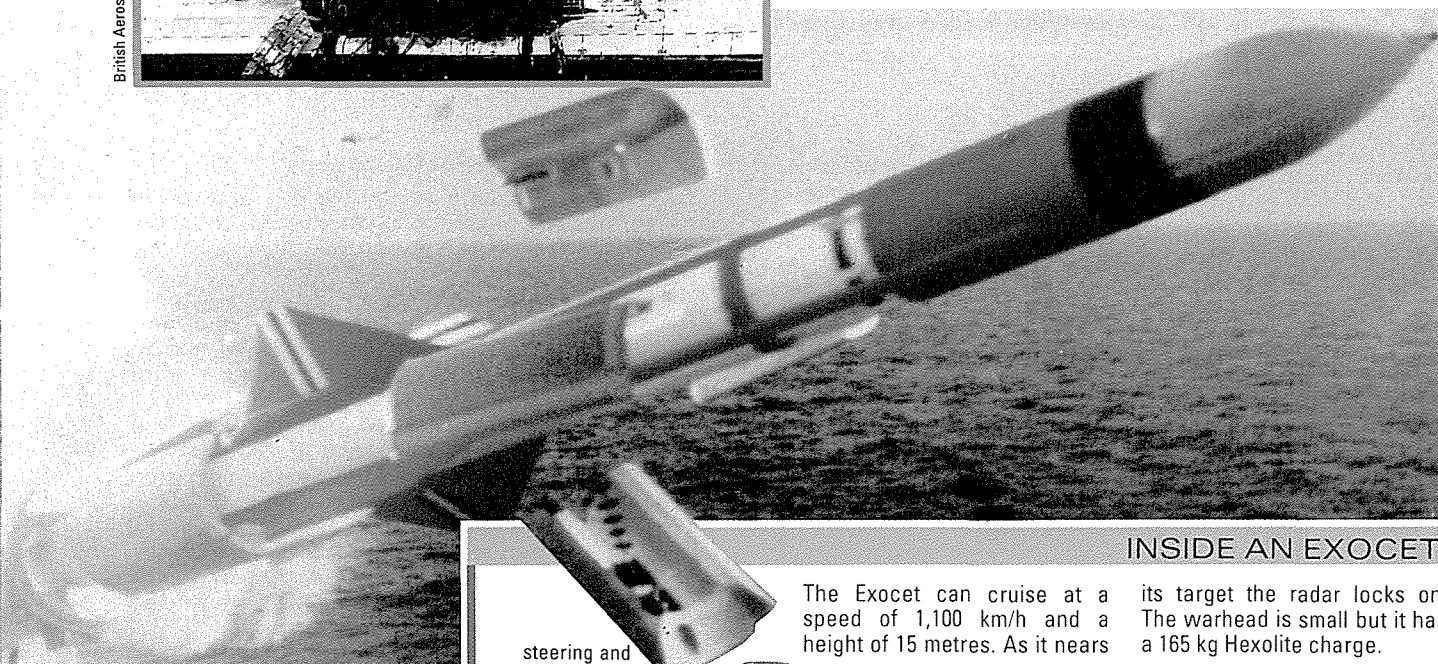
British Aerospace

Sea-skimming missiles pose a serious threat in sea warfare, as was illustrated by the damage caused to HMS Devonshire during a deliberate controlled firing exercise.

THE DEADLY EXOCET

FLOATING FORTRESSES

NUCLEAR SUBMARINES

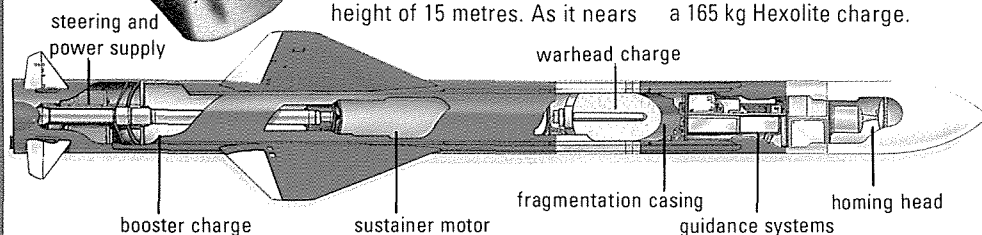


Frank Spooner Pictures

INSIDE AN EXOCET

The Exocet can cruise at a speed of 1,100 km/h and a height of 15 metres. As it nears

its target the radar locks on. The warhead is small but it has a 165 kg Hexolite charge.



John Houghton

An MM40 Exocet roars into life. The pieces flying off are spacers, which guide and protect the missile during its journey through the launcher. After launching, they are no longer needed and are discarded automatically.





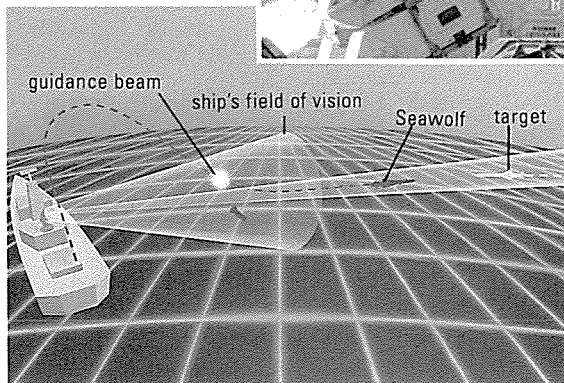
length, 350 mm in diameter, and has a one metre wing span. Before launching, its computerized guidance system is provided with information, such as the bearing and range of the target ship and the height it must fly above water. After launching, the missile's rocket motor takes it to a speed of Mach 0.93 (1,140 km/h) - almost the speed of sound - as it dives to wave-top height, and then skims over the sea's surface, towards the enemy ship.

When the Exocet is within 14 km of its target, it automatically switches on its radar scanner. The scanner detects the target, works out how far the missile is off course (the

Seawolf is the latest generation of Royal Navy air defence missile. Entirely automatic and self-guiding, it can set itself to explode, either when it hits the target, or when it is close to the target.



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The highly accurate guidance method used by Seawolf is known as Command to Line of Sight (CLOS). Electronic equipment on the carrier ship tracks the target. Seawolf is then steered towards it by a beam of guidance commands.

target may have moved in the two or three minutes since the missile was launched) and then points it in the right direction for a direct hit. If it doesn't make a direct hit, a fuse will automatically set the warhead off close enough to cause major damage to the target ship.

The firepower of Exocet shown during the Falklands conflict in

1982 led to many countries producing their own, more sophisticated versions. Typical examples are the Israeli 'Gabriel', the Italian 'Otomat' (which uses a rocket booster to launch it) and the British Sea Skua - one of the few sea-skimmers to be launched from a helicopter.

Probably the most formidable of all missiles, however, is the Russian SS-N-3 Shaddock - whose maximum range of 750 km dwarfs that of its European counterparts, with their range of 50-70 km.

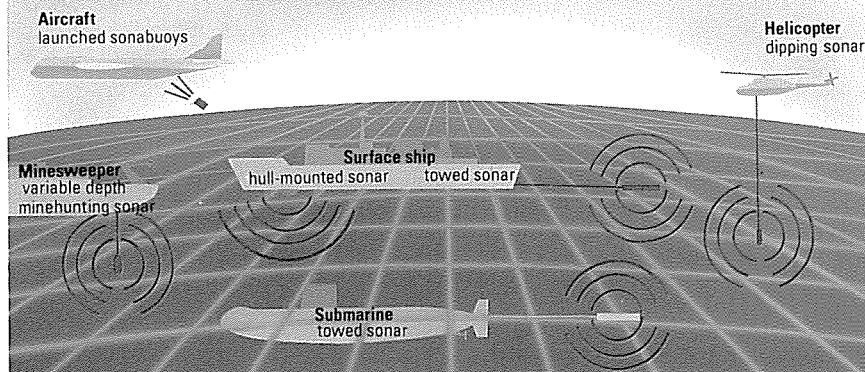
SONAR GUIDE



TRH Pictures

Sonar operators use advanced display techniques to monitor enemy positions. Whereas radar uses radio waves, sonar uses high frequency sound waves. Both are vital in modern sea warfare and defence.

Sonar is particularly effective underwater, where it is used to detect enemy shipping, torpedoes and mines. Sonar can be equally effective when controlled by aircraft or sea-going vessels (even fishing vessels carry sonar to detect shoals of fish). Five methods of using sonar are shown below.



Stan North

Missile attack!

As soon as an attack is detected, it is essential to take avoiding action. A ship cannot be moved quickly enough to avoid being hit, so the fast-approaching missile has to be 'put off the scent' - by electronic counter-measures, which would seek to upset its guidance - or destroyed.

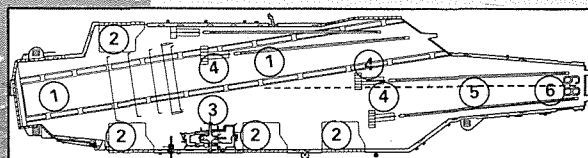
There are two options for counter attack: gun or missile systems. The Americans have opted for a gun system, typified by the 'Phalanx' system, which uses radar to direct a gun towards the missile. Its 20 mm shells are poured out at 3,000 rounds per minute, practically guaranteeing a hit every time.

Seawolf

By contrast, the British Royal Navy has opted for anti-missile missiles, of which the most impressive is Seawolf. The main virtue of this defence missile is its fast reaction time. Within thousandths of a second of detection by the ship's search radar, 'friend or foe' interrogation of the target takes place. At the same time, the range, speed

FLOATING FORTRESS

SIPA Press/Rex Features



The enormous Nimitz class carriers are powered by two nuclear reactors, which provide speeds of up to 30 knots (55.5 km/h). They can remain operational for 13 years before refuelling, and are able to launch their complement of aircraft at the rate of three per minute. Key to flight deck (inset): 1 landing guide-lines 2 aircraft elevators 3 radar/control tower 4 jet efflux deflectors 5 launching catapults 6 identification mark.

and bearing of the potential enemy are keyed into the ship's computer, so that when an immediate threat is identified, the missile is ready to go.

Powered by solid-fuel motors (it has a boost stage for even faster launching), the missile is steered towards its target by guidance commands transmitted in a narrow beam to aerials on the missile. Seawolf will cope with a missile flying at speeds above Mach 2 (2,450 km/h) – twice the speed of sound – and can actually split a shell in half when in flight.

HMS Cornwall, a Type 22 frigate, was commissioned to provide an all round defence capability for the Royal Navy. Designed for anti-submarine warfare, it is fitted with torpedo tubes, and can carry both Harpoon and Seawolf missiles.



Yarrow Shipbuilders

Aircraft carriers

The world's largest and most sophisticated aircraft carriers are the USS 'Nimitz' class carriers. Each ship weighs over 90,000 tonnes, the largest – *Theodore Roosevelt* – being 97,000 tonnes. They are 333

metres long, and carry over 6,000 men and more than 90 aircraft.

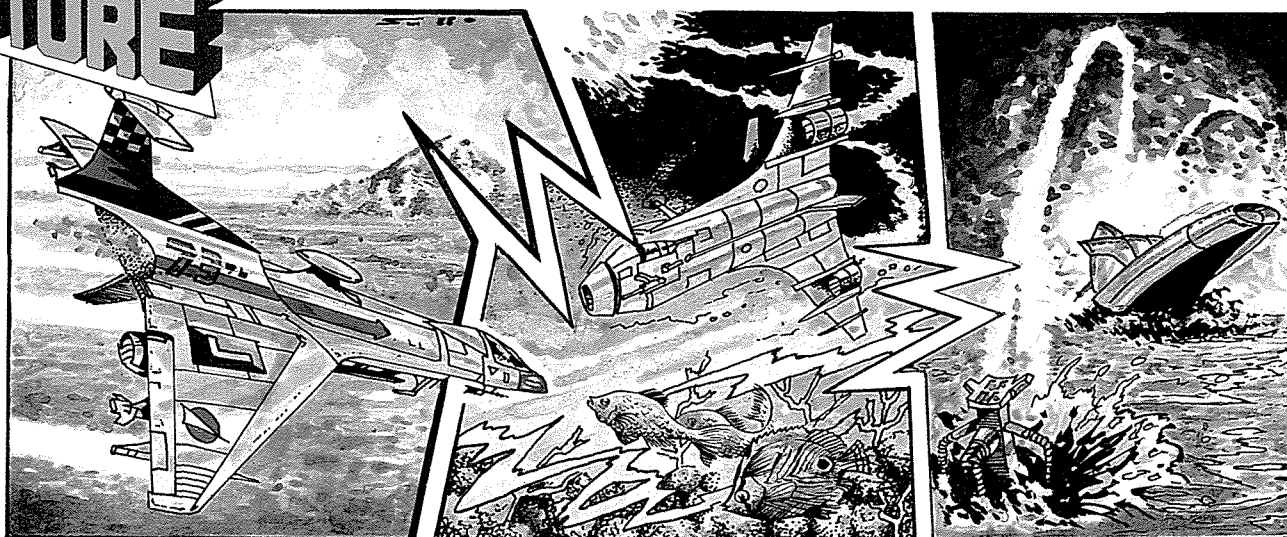
Other aircraft carriers are much smaller. The modern, Russian carriers, known as *Kievs*, weigh about 32,000 tonnes and carry over 20 helicopters and 12 vertical take-off planes. However, the *Kiev* carriers

are no match for the vastly superior US carriers.

Probably the most famous British example of an aircraft carrier is HMS *Invincible*, said to be one of the largest warships in the world to be propelled by gas turbines. Over 206 metres long, it can carry 950 men

INTO THE FUTURE

SUPERSONIC FLYING SUB



▲ The aerosub, or flying submarine, is one of many exciting possibilities for future sea weapons, with a greater potential even than Exocet class missiles.

▲ Aerosub will fly to within a few hundred kilometres of its target, then plunge into the water to avoid enemy radar – moving as fast under the sea as above it.

▲ Accelerating to supersonic speed when approaching its target, the aerosub will burst out of the water and deliver its fatal charge with precise accuracy.



and 25 aircraft, and reaches a speed of 28 knots (52 km/h). At a mere 16,000 tonnes, compared with the massive Nimitz carriers, *Invincible* reflects the recent emphasis on light-weight design.

Standard warships

In the past, battleships and cruisers relied on massive armour plating for protection. Now the emphasis is on light weight and agility, with greater reliance on speed and electronic detection and anti-missile equipment for keeping out of trouble.

The very first nuclear submarine, USS *Nautilus*, was built in 1955, and travelled 530,000 km using only 5 kg of nuclear fuel (a car covering the same distance would have used about 38,000 litres of petrol). In the 30 years

that have passed since then, these vessels have become the most independent, formidable and dangerous craft at sea. Independent because they can spend indefinite periods of time with no outside contact (their nuclear reactor core needs replacing only every few years); formidable because of the sophisticated equipment that runs them; and dangerous because of their weapons – ballistic missiles armed with dozens of nuclear warheads.

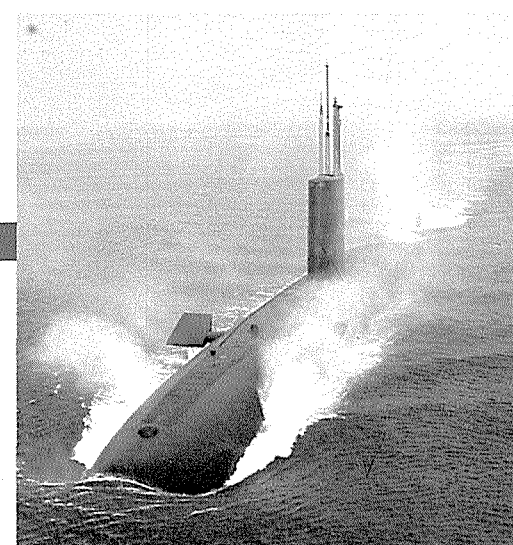
Underwater prowlers

Modern nuclear submarines are built primarily for speed. The fastest in the world are the USSR's Alfa class, which can reach a maximum speed of 42 knots (78 km/h); but there are many others which reach speeds of over 30 knots (56 km/h).

Nuclear subs generally fall into two types – the large SSBNs (ballistic nuclear submarines) and the smaller 'hunter-killer' fleet submarines. SSBNs carry sea-launched nuclear missiles that can be fired underwater, carrying warheads to targets that may be thousands of kilometres away. 'Hunter-killer' types are used to track SSBNs down. These are faster, and are equipped with sensitive sonar to detect the unique 'noise signature' of other submarines, which they stalk and destroy with torpedoes.

A British nuclear sub, HMS Conqueror, on the ocean surface. These 'hunter-killer' subs can remain submerged for years. During the Falklands War, it was Conqueror that sank the Belgrano.

If a nuclear sub runs too shallow, it will break the surface and be seen; too deep and it will be crushed by water pressure. So the sub's exact position is constantly monitored by the Submarine Inertial Navigation System (SINS). This calculates movement in all directions, ensuring that the sub does not move too far off the correct path. It is made up of a series of gyroscopes, and can operate for many days underwater. However, SINS needs to be checked occasionally against the positions of the stars or a point of land.

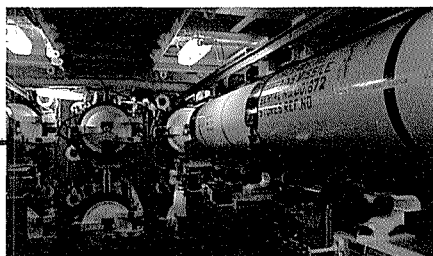
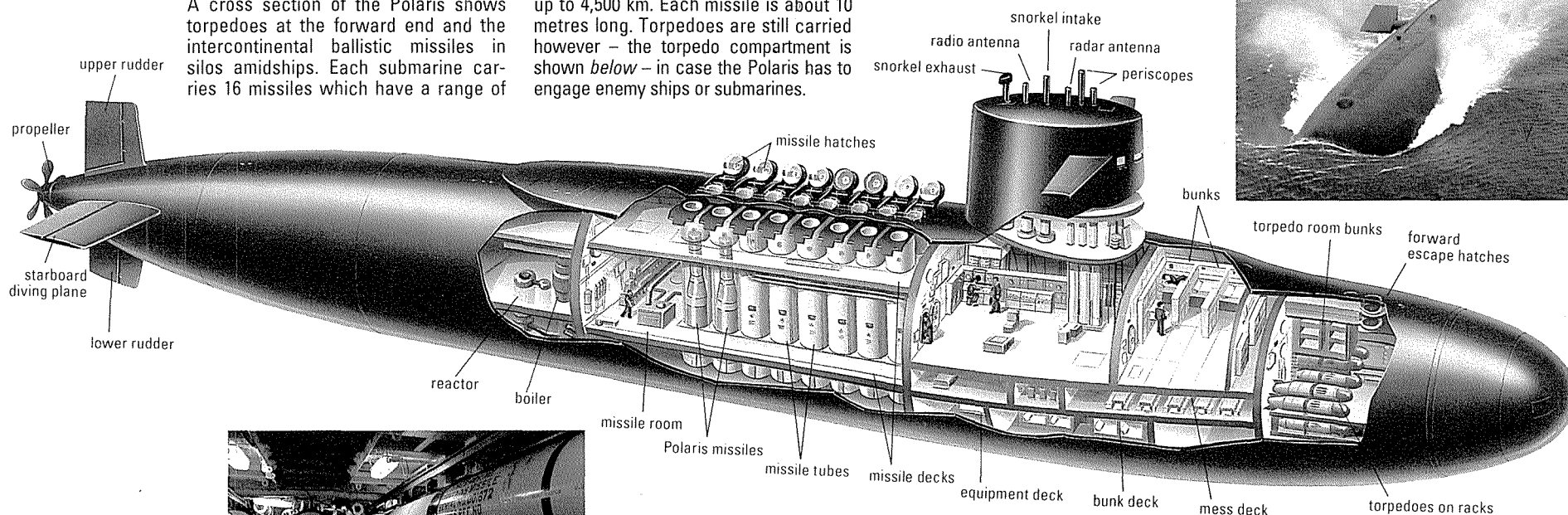


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THE POLARIS SUBMARINE

A cross section of the Polaris shows torpedoes at the forward end and the intercontinental ballistic missiles in silos amidships. Each submarine carries 16 missiles which have a range of

up to 4,500 km. Each missile is about 10 metres long. Torpedoes are still carried however – the torpedo compartment is shown *below* – in case the Polaris has to engage enemy ships or submarines.



Ian Stephens

RESCUE AND SURVIVAL

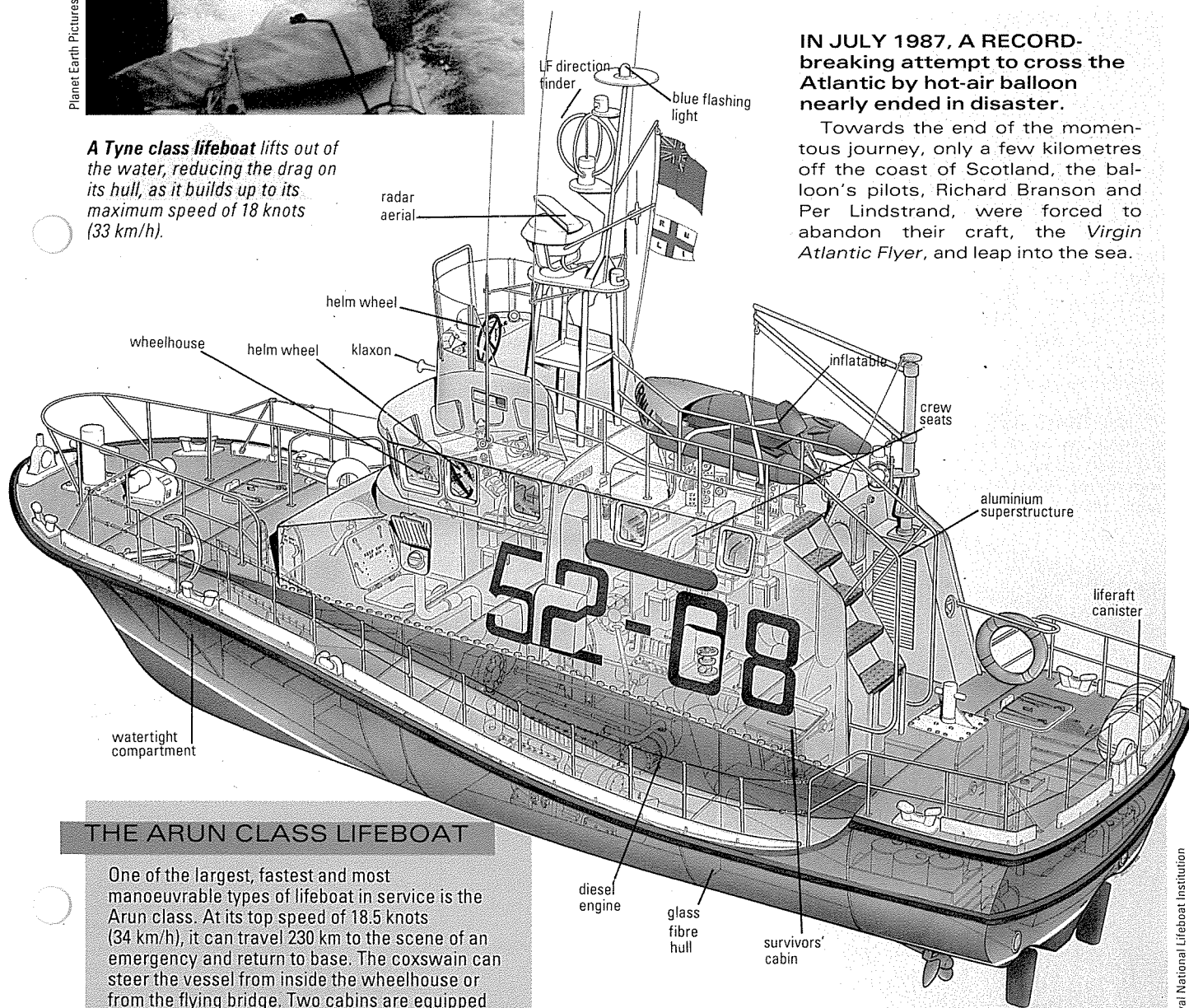
Planet Earth Pictures/T & D Crossley



A Tyne class lifeboat lifts out of the water, reducing the drag on its hull, as it builds up to its maximum speed of 18 knots (33 km/h).

IN JULY 1987, A RECORD-breaking attempt to cross the Atlantic by hot-air balloon nearly ended in disaster.

Towards the end of the momentous journey, only a few kilometres off the coast of Scotland, the balloon's pilots, Richard Branson and Per Lindstrand, were forced to abandon their craft, the *Virgin Atlantic Flyer*, and leap into the sea.



THE ARUN CLASS LIFEBOAT

One of the largest, fastest and most manoeuvrable types of lifeboat in service is the Arun class. At its top speed of 18.5 knots (34 km/h), it can travel 230 km to the scene of an emergency and return to base. The coxswain can steer the vessel from inside the wheelhouse or from the flying bridge. Two cabins are equipped for the care of survivors.

Royal National Lifeboat Institution





A ship in distress is located and survivors wait to be rescued. One crew member called a 'diver' in the Navy is winched down on a rope. Able bodied survivors will be winched back in a harness. The winch is operated by the radar operator or navigator.

A stretcher is sometimes necessary to air-lift injured survivors. The helicopter is able to winch up 270 kg – about the weight of four adult men.



Within minutes, their SOS call had coastguard officials alerting RAF station Dunfermline. Within half an hour, Branson' was lifted from the sea by a Lynx helicopter from HMS Argonaut. Lindstrand was picked up by a lifeboat.

24-hour alert

In order to work hand in hand, the different rescue services are connected on land by telephone and telex lines, and at sea by a multi-

channel radio service. They are on the alert 24 hours a day.

Distress calls can be sent in different ways, but radio-telephone calls on specially reserved channels are the most usual. Automatic beacons powered by batteries or solar cells are carried by ships' lifeboats and are even fitted to some lifejackets.

Signalling lamps, torches or emergency transmitters can send the Morse signal SOS – three dots,

three dashes, three dots – the internationally recognized call for immediate assistance. In time, however, Morse signals will be replaced by the Global Maritime Distress and Safety system.

Lifeboat rescue

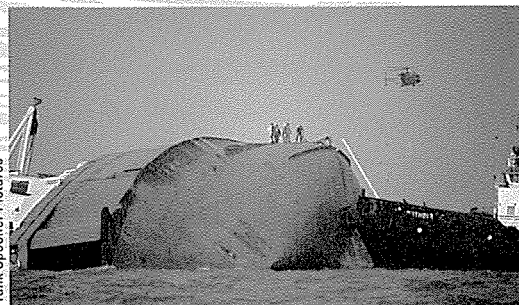
In the UK, the Royal National Lifeboat Institution (RNLI) provides a 24-hour sea rescue service around the coasts. It has 204 lifeboat stations, 128 large lifeboats (10–21 metres long), 133 smaller ones (5–6.5 metres long) and 133 inflatable lifeboats. Inflatables have been introduced to deal with the growing number of incidents involving water sports enthusiasts, mainly in in-shore waters. The inflatables are virtually unsinkable and fast. Twin-engined versions can reach 30 knots (55 km/h).

The RNLI's sophisticated high-performance craft can get to a vessel in distress up to 50 km from the shore within four hours (or as little as two hours for some of the faster boats).

Many of today's lifeboats are 'Fast Afloat Boats' (FABs), which

FERRY DISASTER

At 7.20 p.m. on 6 March 1987, a dredger captain in the Belgian port of Zeebrugge radioed that the British ferry *Herald of Free Enterprise* was capsizing. The Belgian Sea Rescue Service co-ordinated the massive rescue operation that instantly swung into action. A Sea King helicopter, tugboats, other small craft and divers helped save 300 of the 500 passengers.



means that they are kept afloat in a harbour or inlet, rather than launched down a slipway.

Rescue by air

The fastest rescues of all are carried out by helicopters. In the UK, they are mostly operated by the Royal Air Force and Royal Navy.

A Wessex helicopter can normally carry ten rescued persons in addition to its three-man crew. A Sea King can take 16 people as well as its four-man crew. But in an emergency, either type can take far more people on board, jettisoning fuel if necessary to lighten the craft.

KEYS TO SURVIVAL

If you have to wait for rescue after finding yourself adrift, or after capsizing follow these four basic survival rules:

- Stay with the craft. Not only will it shelter you, it will give you something to hold on to so that you can conserve your energy.
- If you have to enter the water, try to do so gradually. The shock of cold water can be dangerous.
- Stay warm. Don't shed clothes and move as little as possible (water moving past you takes heat away). Keep your face as dry as possible. If you're with others, huddle together.
- Don't tire yourself. Try to move as little as possible, and tread water rather than swim any distance.

Just amazing!

ENDURANCE AT SEA
MAN'S CAPACITY FOR SURVIVAL AT SEA IS REMARKABLE. IN 1942, A SHIP'S STEWARD, POON LIM, LIVED FOR 133 DAYS ON A RAFT WITH ONLY 50 DAYS' WORTH OF FOOD AND WATER. AFTER HIS SHIP WAS TORPEDGED.



external tank separation.
OMS engines take the Shuttle
into its operating orbit

FLYING THE SHUTTLE

THE RE-USABLE SPACECRAFT



SATELLITE REPAIRS



ORBITER LANDING

main engine cut-off
after 8½ minutes

3½ throttling to maintain
moderate acceleration

separation of
solid rocket boosters

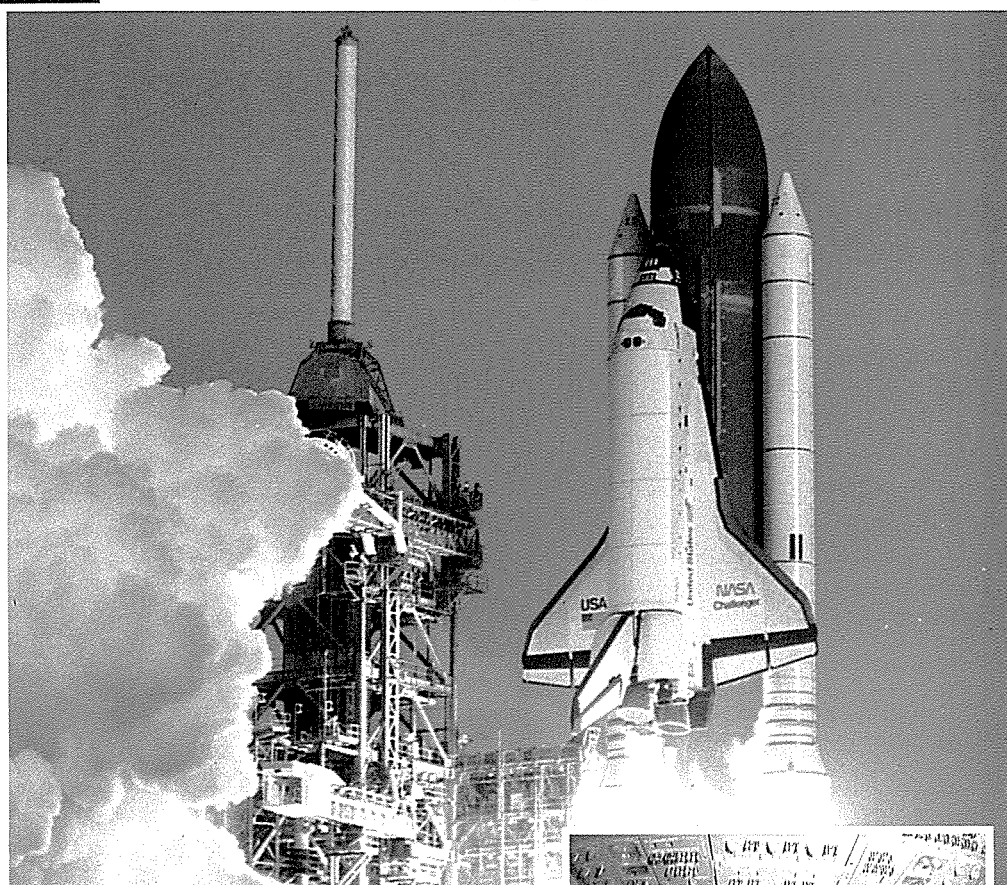
burn out of boosters
two minutes after take-off

ascent stage using booster
rockets and main engines

splashdown of solid
rocket boosters

recovery of rockets
for refurbishment

prelaunch stage, controlled
from launch site



GUSHING A WHITE GEYSER OF flame, the USA's Space Shuttle slowly lifts clear of its launch tower – then rapidly accelerates. Just eight minutes later, bearing its crew and cargo, the Shuttle reaches Earth orbit about 200 km above the ground.

Unlike an ordinary rocket, the Space Shuttle is designed to be used over and over again. It has four main parts: the orbiter (shaped like a chunky aeroplane), two solid rocket boosters (SRBs), and a large external tank.

At lift-off, the twin SRBs and the three main engines at the back of the orbiter all fire together. The SRBs provide the real 'muscle' to get the Shuttle off the ground and build up speed. Two minutes into



NASA

The Shuttle's flightdeck is dominated by the flight computer, which reads out to the three central screens. Shuttle astronauts wear space suits during launch and landing in case of emergency.

NEW TECHNOLOGY 7



Just amazing!

MONKEY BUSINESS

THE SHUTTLE HAS THE REPUTATION OF GIVING THE SMOOTHEST RIDE IN SPACE – TAKING OFF LIKE A ROCKET AND LANDING LIKE A PLANE. AND YET MORE THAN HALF THE ASTRONAUTS – BOTH HUMANS AND MONKEYS – WHO HAVE FLOWN IN THE SHUTTLE, HAVE SUFFERED FROM SPACE SICKNESS WHICH LASTS ABOUT TWO DAYS.

Paul Raymond



the flight, their fuel is used up and they fall into the sea on parachutes.

Meanwhile, gulping in liquid fuel from the external tank, the orbiter's three main engines continue firing for another six minutes. By the time they cut out, the orbiter is at the edge of space and ready to make its final course correction to enter Earth orbit. The external tank is jettisoned and burns up as it hurtles back down through the atmosphere. It is the only part of the Shuttle that cannot be re-used.

Tasks in Orbit

Usually between five and seven crew members are involved in a Shuttle mission. Once in space, their job may be to launch satellites out of the orbiter's payload bay, or even go outside to fix a spacecraft.

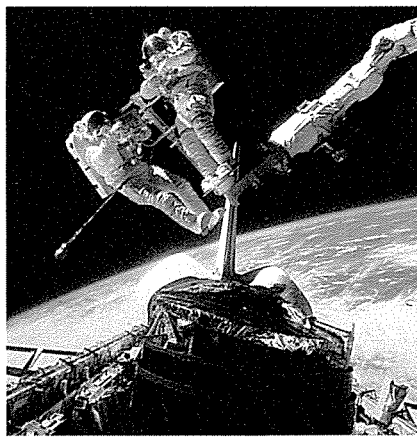
Using a Manned Maneuvering Unit (MMU) – a special backpack fitted with small thruster jets – an astronaut can move freely up to about 100 metres away from the Shuttle. In this way, satellites may be repaired 'on site' or placed into

the Shuttle's hold and brought back to Earth.

For launching satellites and doing other heavy work, the Shuttle's payload bay is equipped with a robot 'manipulator arm' that can be operated by a crew member from inside the orbiter. Often, a communications satellite has to be placed 35,900 km above the equator, where it will orbit in time with the Earth's spin. The Shuttle, however, is limited to orbits below 1,100 km. Therefore, the satellite is sent spinning gently up out of the payload bay. Then a booster rocket fitted to the satellite fires and lifts it into the required orbit.

A Shuttle mission may last up to 30 days. Then the orbiter glides back down to Earth. Special thermal tiles help protect the spacecraft as its surface heats to 1,500°C, when it plunges into Earth's atmosphere at a speed of 27,000 km/h.

Finally, the orbiter lands on a runway as if it were an ordinary plane. A specially adapted jumbo jet then carries the orbiter piggy-back to its launch site to be made ready for the next flight.



Stepping out into space, two astronauts from Discovery retrieve a satellite that was stranded in orbit.

DISASTER IN THE SKY

On the afternoon of Tuesday, 28 January 1986, 73.6 seconds after launch, the Shuttle, *Challenger*, exploded, killing all seven crew members. The cause of the explosion is thought to have been a faulty seal on one of the booster rockets, which allowed the hot gases being burned to escape. These gases, at 3,100°C, instantly caused a massive explosion that blew the Shuttle apart. The two boosters continued flying until they were destroyed seconds later.

The *Challenger* disaster brought the Shuttle programme to a temporary halt while the boosters were redesigned. A new orbiter, *Endeavour*, was built to replace *Challenger* at a cost of \$2 billion; its first flight was in May 1992.

Frank Spooner Pictures



deorbit burn, using the manoeuvring engines to slow the spacecraft



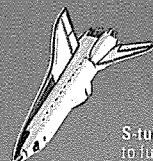
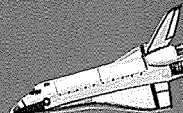
heat builds up in the atmosphere causing a communications blackout



maximum heating, with the nose and leading edges reaching 1500°C



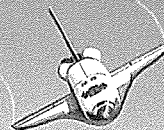
communications restored as the Shuttle slows and turns into a glider



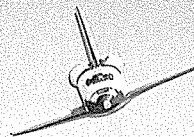
S-turns are performed several times to further slow the Shuttle



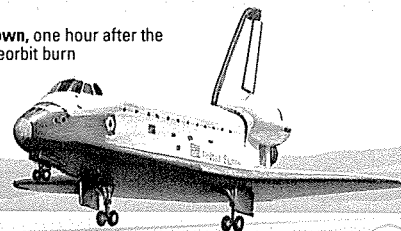
automatic landing phase begins two minutes before touchdown



final approach with the split rudder acting as an airbrake



touchdown, one hour after the initial deorbit burn



David Parker



STAR WARS

X-RAY LASERS

KILLER SATELLITES

INTERCEPTOR ROCKETS

early warning satellite signals the launch of hostile missiles to the control centre which then brings defensive weapons into action

chemical laser waits in orbit in readiness for an attack

particle beam gun directs a fast-moving stream of atomic particles that disables the missile's electronics

orbiting mirror directs the laser beam onto the target

electromagnetic rail gun accelerates small, heat-seeking projectiles to enormously high speeds, like bullets from a gun

x-ray laser, powered by a small H-bomb, pops up from a nearby submarine

radar stations detect and track enemy missiles as they fall to their target

ground-based laser battle station generates a high energy laser beam that can burn its way through a missile's casing

Ian Stephen

AN ALARM BELL suddenly sounds in the secret underground headquarters of America's defence command. The United States and its allies are under massive nuclear attack.

Speedily, orders are sent up to a fantastic array of weaponry circling around the Earth. Laser beams flash and interceptor rockets soar from

their launch-pads in an all-out effort to destroy the enemy missiles before they strike their targets. Within just half an hour, World War III is over.

In 1983, President Reagan announced that it would be a goal of the United States to develop a space-based defence system against possible nuclear attack. Officially called the Strategic Defence Initiative, or SDI, the scheme immediately became better known as 'Star Wars'.

About 2,000 intercontinental

missiles based in the CIS are aimed towards the United States. Some of these are capable of carrying six to 10 separate warheads, which are ejected with several decoys to confuse the enemy. The warheads are guided independently to their targets, taking only 30 minutes to make the 8,000 km journey. The Star Wars system is designed to ensure that no Russian or other warheads arrive on American soil - each missile to be blown to pieces while still in flight.

Spy satellites and ground-based radar would provide the first warning that a nuclear attack was underway. Their data would be fed automatically to a group of powerful



computers at defence headquarters. Information on the position and course of each enemy missile would be worked out and passed on to a series of computers located around the United States. From these, commands would flash up to the various Star Wars weapons waiting in Earth orbit.

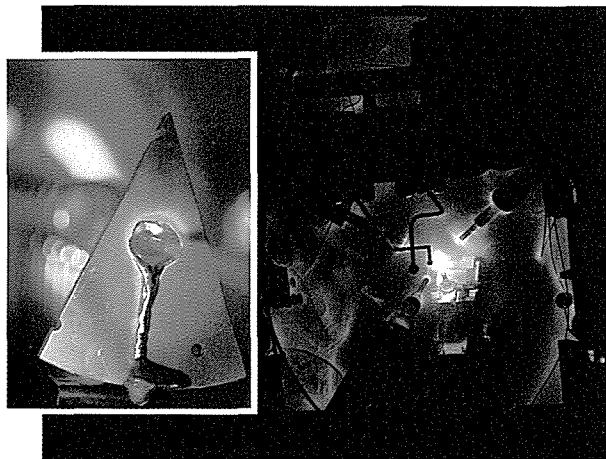
Less than five minutes after being launched, the first wave of enemy missiles would be met by a volley of laser beams. Lasers send out a powerful concentrated beam of

laser beams on to their targets.

As they hurtled above the atmosphere, hundreds of the enemy missiles might be destroyed by the defensive lasers. Yet hundreds more would escape. Other Star Wars devices would then come into play. Bizarre weapons known as rail guns would use a long chain of strong magnets to shoot out projectiles at very high speeds.

Powered by a nuclear reactor, each rail gun would be capable of firing at least twice a second, iden-

Beam guns set up in the laboratory. A particle beam gun (inset) burns a hole in a piece of aluminium. This kind of beam can destroy electronic circuits within a missile's casing. It is also unaffected by the Earth's magnetic field. This means it can be fired in straight lines at very distant objects.



SPL

light that can burn its way through a missile's casing. Laser beams travel at the speed of light, 300,000 km/s. Some of the lasers would be carried on board spacecraft flying high above the Earth's surface.

The huge space-based lasers would lock on to their targets with pinpoint accuracy and fire concentrated bursts of energy at them. At the same time, beams from ground-based lasers would hit five metre wide orbiting mirrors, which would reflect the powerful, destructive

tifying the target using heat-seeking sensors. The charged-particle guns would send beams of atomic particles that could penetrate the missile and disable the electronics inside.

Enemy missiles that managed to evade both the lasers and the back-up equipment would be met by a final salvo of interceptor rockets. Launched from the ground, these interceptors would simply ram into

STAR WARS SPIN-OFF

Some of the equipment currently being researched for SDI could eventually find a peaceful use. One team of NASA scientists, for instance, has suggested that a rail gun could be employed to hurl small probes into space. Each probe, equipped with advanced micro-circuits might be no bigger than a coffee jar and weigh only 1-2 kg. Catapulted away from the Earth at a very high speed, such a tiny spacecraft would take only a few years to reach Saturn.

and destroy any objects in their path. This, though, would be very much a last-ditch effort. In theory, the SDI lasers should be all that is necessary.

Yet, theory is all that Star Wars is. Most of the technology for an SDI system has still to be developed. So far, no weapon like a rail gun has been built and no-one knows how well it would work in practice.

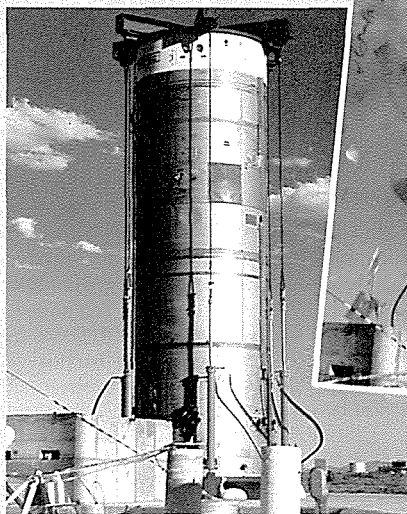


A real possibility?

However a limited SDI programme known as GPALS (Global Protection Against Limited Strikes) is proceeding satisfactorily. It is a space-based system called 'Brilliant Pebbles', consisting of surveillance sensors. It fires solid objects at great speed into the path of incoming missiles, and uses ground-launched, anti-ballistic, missiles as a last line of defence.

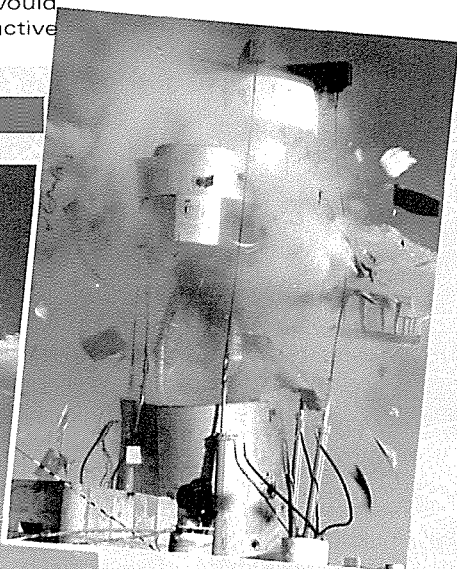
Another argument against Star Wars is that other countries might develop 'killer satellites'. These orbiting spacecraft would destroy the surveillance satellites, lasers and other weaponry upon which the SDI system depends. However, with the end of the Cold War, there is the possibility of US-Russian cooperation in Star Wars systems.

LASER POWER



US Department of Defense

Before: Part of a Titan I Missile sits in the New Mexico sun ...

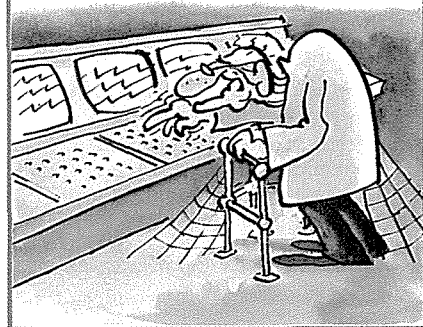


After: ... and is blown to smithereens by a high-energy laser beam. This test proved the power of MIRACL, the Mid-Infrared Advanced Chemical Laser, one of the lasers to be used in SDI.

Just amazing!

WORKING OVERTIME

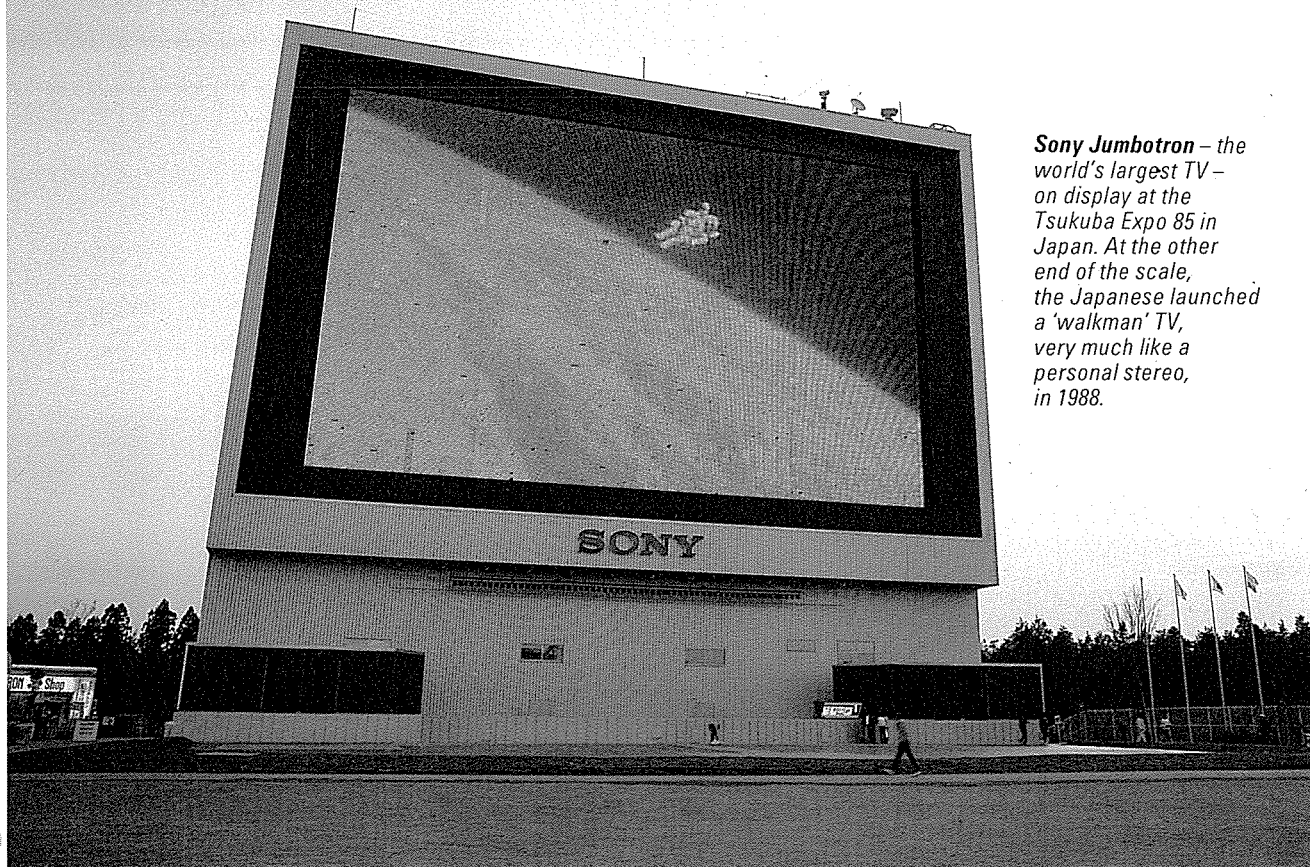
TALK OF STAR WARS IS ALL VERY WELL, BUT TO PROGRAM ALL THE SUPER-COMPUTERS FOR EVEN THE WESTERN DEFENCE SYSTEM WOULD TAKE ONE MAN 30,000 YEARS TO COMPLETE.



Paul Raymond



INSIDE RADIO AND TV

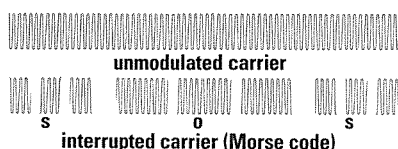
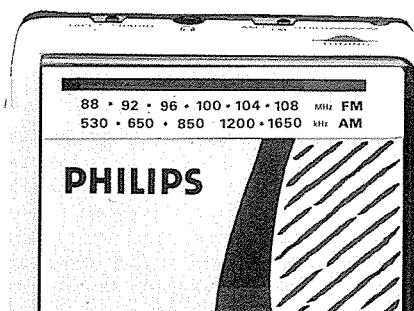


Sony Jumbotron – the world's largest TV – on display at the Tsukuba Expo 85 in Japan. At the other end of the scale, the Japanese launched a 'walkman' TV, very much like a personal stereo, in 1988.

Spectrum Colour Library

IMAGINE A TELEVISION SET, covering one entire wall of your living room. Imagine being able to view two or more programmes at once – watching an adventure film while keeping an eye on a football match.

Soon all this will become possible through advances in electronic technology and production techniques.



A radio transmitter normally sends out a continuous signal. Morse code can be transmitted by switching the transmitter on in short and long bursts to produce 'dots' and 'dashes'. To transmit speech

Since it started in the 1930s, television broadcasting has made tremendous technical progress. Today, it can entertain, inform, and educate us. Into our homes it brings pictures and sounds of events from wars to royal weddings, from sporting competitions to the drama of a hijacking. Not only can we view such events first hand, but with the addition of videotape, we can freeze, replay and even zoom in to particular sections of the picture. Soon these facilities may even be incorporated into the TV set itself.

Radio, too, has emerged as a vital

information medium in the modern world. Indeed, it was the invention of radio that eventually led to the birth of television.

Radio broadcasting

By comparison with the electric telegraph, and even the telephone, radio seemed to offer an almost miraculous way to communicate. Silent and invisible, radio waves could carry Morse code signals through the air without any need for electrical cables. In 1896, the Italian inventor Guglielmo Marconi became the first person to send 'wireless' signals over a distance of several kilometres. Five years later, he beamed a message all the way across the Atlantic. Thus came about what in Britain was called 'wireless telegraphy' and in the United States 'radiotelegraphy', or 'radio' for short.

It was soon discovered how to use radio to transmit not just coded signals, but also speech and music as well. The trick was to use the sound signals from a microphone to vary the radio waves in some way. The radio waves thus 'carried' the sound information. This is why engineers refer to the radio signal as the 'carrier'.

The first method used to superimpose sound signals on radio waves was amplitude modulation

SIGNALS BY RADIO



AM: carrier amplitude modulated with sound signal

FM: carrier frequency modulated with sound signal

or music, the sound signal is made to modulate (vary) either the amplitude or the frequency. This produces an amplitude-modulated (AM) or frequency-modulated (FM) transmission.



(AM). The sound waves were used to vary the amplitude (strength) of the carrier. Amplitude modulation is still used in radio today. Depending on their wavelength, AM radio broadcasts may be short wave (SW), medium wave (MW), or long wave (LW).

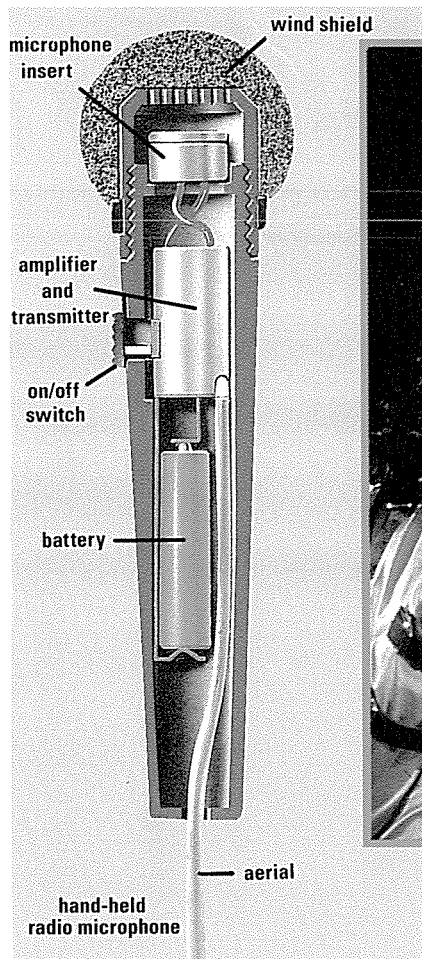
Since the end of World War II, frequency modulated, or FM, radio has also become popular. In frequency modulation, the sound signal varies the frequency of the carrier – the rate at which the radio waves are produced. Unlike AM radio, FM is generally unaffected by interference from other radio stations, motor cars and lightning. Try tuning first into an AM station and then into a station on the FM band. The difference in sound quality will be obvious immediately.

Suppose you are listening to

SMART RADIO

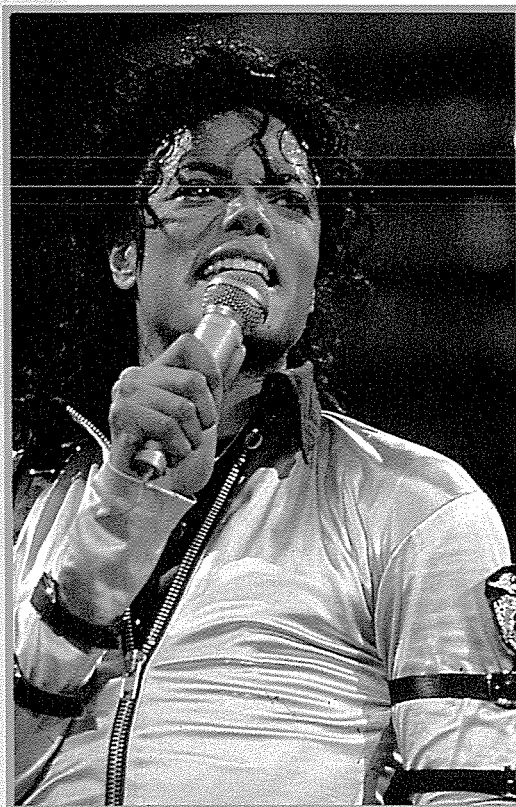


With so many radio stations to choose from, it is often difficult to find the one you want. The Radio Data System (RDS) provides a solution. The transmission carries an extra, inaudible signal containing data about the programme. Inside the receiver, a special microchip sorts out this data and displays it on a small indicator panel. The receiver will automatically switch to the strongest signal if more than one transmitter is broadcasting the programme you want.



someone talking on the radio. Whatever form of modulation is used, the radio signal – the modulated carrier – is radiated from a transmitting aerial.

The aerial of a radio receiver picks up radio signals from thousands of stations and turns them into tiny electric signals. A tuning circuit in



Hex Features

Radio microphones are popular with rock stars as they have no trailing cable to restrict their movements. Inside the microphone case is a tiny transmitter, which sends the sounds via a short aerial to a nearby receiver connected to the amplification system.

the receiver allows you to select the signal you want. Other circuits strengthen the signal and demodulate it – that is, extract the sound signal from it. This is then further strengthened and passed through a loudspeaker, which thus reproduces the original sounds from the radio studio.

Inside the box

Television, too, makes use of radio signals that are sent through the air. The difference is that a TV transmission carries both sound and vision signals. The sound signals come from microphones, and the vision signals are formed in the television cameras. Vision signals contain all the information needed to reproduce pictures on a TV screen.

A roof-top aerial picks up the broadcast TV signal, converts it to a small, varying electric current, and then passes this to the television set. The sound portion of the signal is played through a loudspeaker, while the picture information controls the way in which the image is re-formed on the screen.

Spitting out a stream of tiny particles called electrons, the electron gun inside a black-and-white

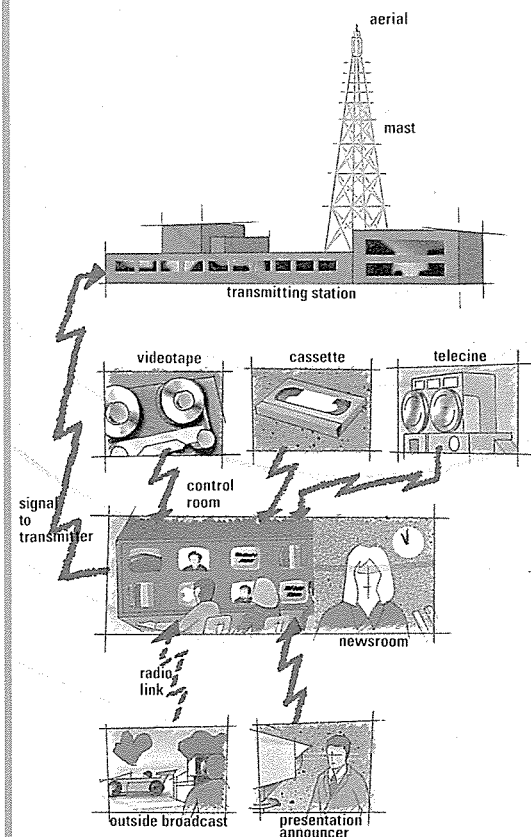


CB JARGON

carpet crawler young child
chew and choke cafe
coffin boffin old person
confetti snow
dandruff snow
dinosaur juice petrol
fishtank bus
fly in the sky aircraft
fuzz buster radar detector
greasy side up overturned vehicle
maniac garage mechanic
motion lotion petrol
nosebag take-away food shop
one-way taxi hearse
panty stretcher fat person
plain wrapper unmarked police car
Rembrandt house painter
press the sheets go to sleep
roach coach garbage truck
run out of road have accident
seat cover passenger
skid lid crash helmet
splat hat crash helmet
thumb-job hitch-hiker
zeds sleep

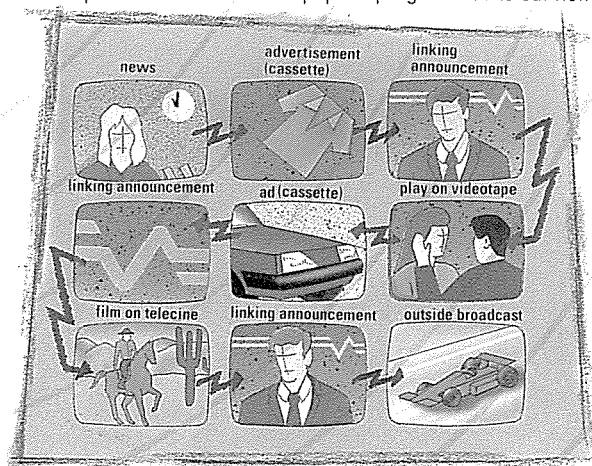
bandage factory hospital
bear in the air police helicopter
body lotion drink
bone box ambulance
brain bucket crash helmet
brain-donor idiot
bubble trouble puncture
bumble bee motorbike

HOW THE IMAGE ARRIVES



The pictures we see on our TV screens come from many different sources. Items that come to us 'live' — at the time they are made — include news material, weather forecasts, and linking 'presentation' announcements between programmes. Outside broadcasts, such as live sports events, are often beamed to the TV studios by special radio-link equip-

ment. However, most of the programmes we watch are pre-recorded. Films made for the cinema are played to us on telecine machines. Television drama is replayed on videotape machines, and advertisements come to us from video cassette machines. Signals from all these sources pass through a control room to the TV transmitter, which beams the programmes to our homes.

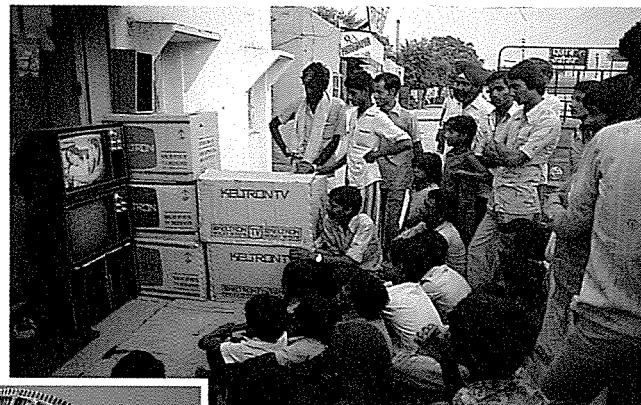


Yanos Matfy

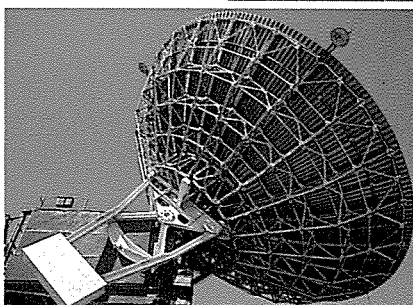
television picture tube rapidly 'scans' the whole surface of the screen, line by line. The inside of the screen is coated with a chemical called a phosphor, which glows according to the strength of the electron beam striking it. The vision signal regulates the strength of the electron beam and thus controls the brightness of each point on the screen as the beam passes over it. In this way, the vision signal, representing the brightness of each point in the original scene, produces a replica of it on the screen.

Dish antennas for receiving satellite TV broadcasts are becoming a common sight on private homes in Europe. The cost of this new technology has decreased considerably in recent years, and satellite services in the UK are about to expand even more.

TV satellite broadcasting may be relatively new to Europe, but India has had a system of direct broadcasting since 1975. A dish antenna (inset) beams the signals to a communications satellite, which re-transmits them to receiving dishes nationwide.



Hutchinson Library



Twenty-five times a second, the electron gun scans the entire screen, creating a slightly different image each time. To the eye, the result is a continuously moving picture.

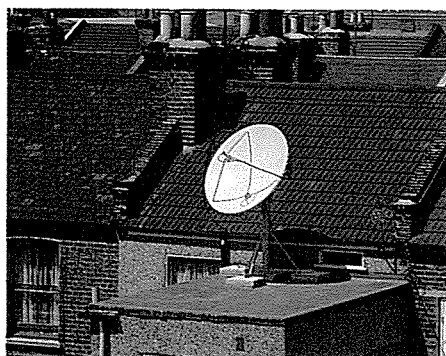
Colour television works in a similar way to black and white TV. But the vision signals contain information on colour — not just brightness.

Instead of just one electron gun, the tube in a colour TV set uses three — one for each of the primary

colours, red, green and blue. Arranged along each line of a colour TV screen are hundreds of groups of three phosphor dots, which glow red, green or blue when struck by an electron beam. Beams from the three guns scan the screen together, each striking only one type of phosphor dot. Thus the three beams each control one of the primary colours in the picture. Different proportions of the three colours produce different colours, when viewed from a distance. This is why a multicoloured picture can be reproduced from dots of just three primary colours.

Cable and satellite TV

For a long time, cable has been used to carry TV broadcasts to remote areas or to blocks of flats that would otherwise need large numbers of aerials. Recently, though,

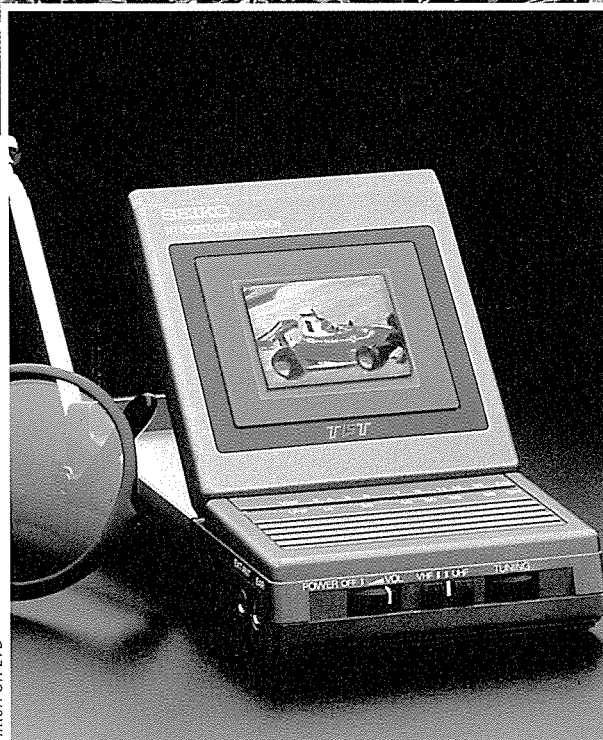


Alex Bartel/SPL



Giant TV screens allow everyone to get a close-up view at open-air rock concerts and sports events. Popularized in the US, these huge screens allow instant replay, commentary and advertising.

Miniature TV sets were just a dream in the days when the average receiver was the size of a large cupboard. But the invention of the microchip, and vast improvements in display technology, have made the pocket TV set a reality.



Hitachi UK LTD

entirely new TV stations have been set up that broadcast exclusively by this means. Cable also makes possible interactive TV. In this, viewers can take part in quiz shows or live debates, simply by pressing buttons on a hand-held unit.

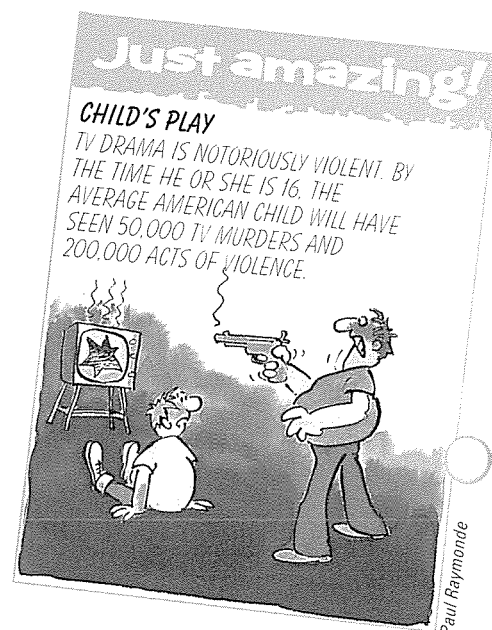
Another recent development is direct broadcasting by satellite, or DBS. By means of a small dish aerial, TV signals beamed out from all parts of the Earth, and relayed by

communications satellites, can be picked up in the home. Already both satellite and cable TV are greatly increasing our choice of television programmes, adding specialist channels for news, sport, films, music and weather to those that are already available.

With the push of a button, today's television can be switched from its usual role to a device for retrieving information. All you need

to make use of this facility is a remote-control device and a TV fitted with circuits for decoding teletext signals.

Teletext consists of hundreds of screen-sized pages of information. News summaries, sports results, programme guides, recipes, weather forecasts, travel information, and even jokes and brain-teasers can be called up almost instantly.



THE PRINT BUSINESS



Sporting Pictures

MORE INFORMATION TODAY is available instantly at the touch of a button. But in spite of this, books, magazines and newspapers remain a popular form of communication.

Until the late 1960s, many of the techniques for printing had changed only slowly from one generation to the next. But now, increasingly, it is the computer and the laser that print the material we read.

The coming of colour

Colour books and magazines appeared only in the last 50 years. Look at the illustrations on this page with a magnifying glass, and you will see they are made up of thousands of tiny dots. Just four different colours are used — the primary colours, yellow, magenta and cyan, together with black. From different combinations of these, any other colour can be printed.

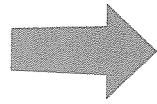
To print in colour, the original colour picture is first put through a 'scanner'. This is a highly sophisticated electronically controlled machine that breaks down the picture into the four basic colours. Each colour is also broken down into a dot pattern. The bigger the dots, the denser the ink on the page and the darker the image appears at that point. Light areas of colour are represented by small dots.

The four colour-dot patterns are printed on four separate films and these, in turn, are used to transfer the dot patterns on to individual metal plates. The dots on each plate are inked in their respective colours and are then transferred — printed — one over the other, so that, together, they once again form the whole colour picture.

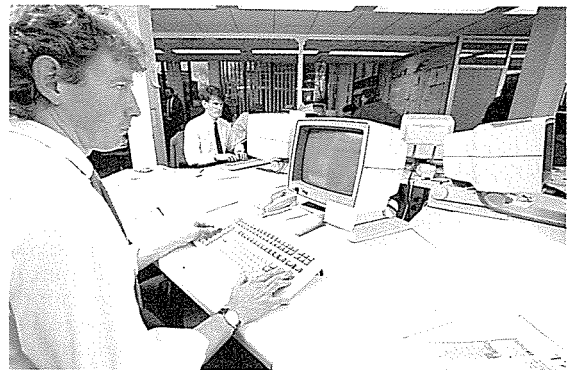
Hot metal type

Until just a few years ago, all national newspapers in Britain were printed by machinery that was nearly 60 years old. The article that a journalist had written was prepared for printing on what was called a Linotype machine.

An operator tapped out the



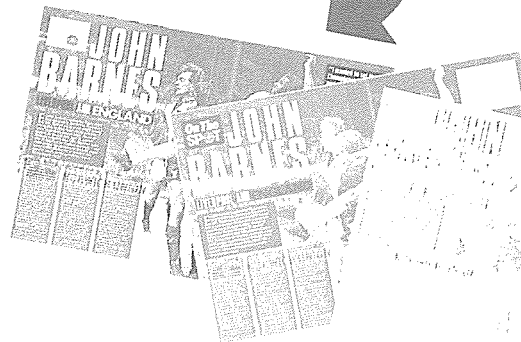
A reporter and photographer at the match send in an article and pictures to the magazine.



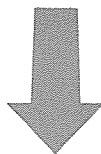
The Independent

Journalists edit the article and pictures to fit the page design.

The pictures and typeset article are separated into four basic colour plates.



Shoot Magazine

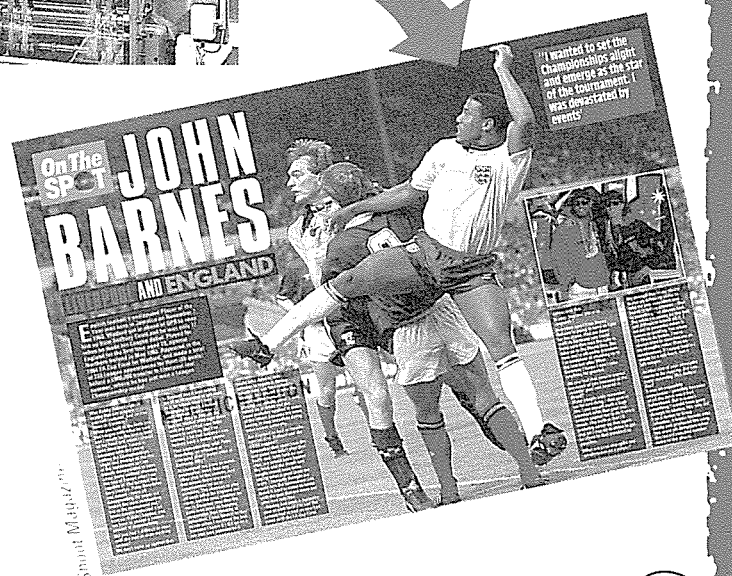


The printer uses all four colour plates to print from.



The finished printed pages are folded and bound into the magazine that goes on sale.

That winning kick is captured for ever in print. From the match, the reporter sends in the story and the photographer, the pictures. Journalists refine the words and pictures ready for publication. The text is set in type, while the pictures are 'colour separated'. At the printers, they all come together in the final printed page.



words at a keyboard similar to a typewriter's, which translated them into a series of punched hole patterns in a tape. When this tape was fed into the machine, it was 'read' and solid lines of type were built up from a pot of molten metal – hence the name 'hot metal'.

The lines were all stacked in type holders called galleys and arranged as they would appear on the printed page, together with any plates for printing pictures. This arrangement of type and plates, called a forme, was clamped together in a metal frame called a chase. Printing plates were then made from impressions of the formes. These plates were wrapped around cylinders, inked and used to print the pages.

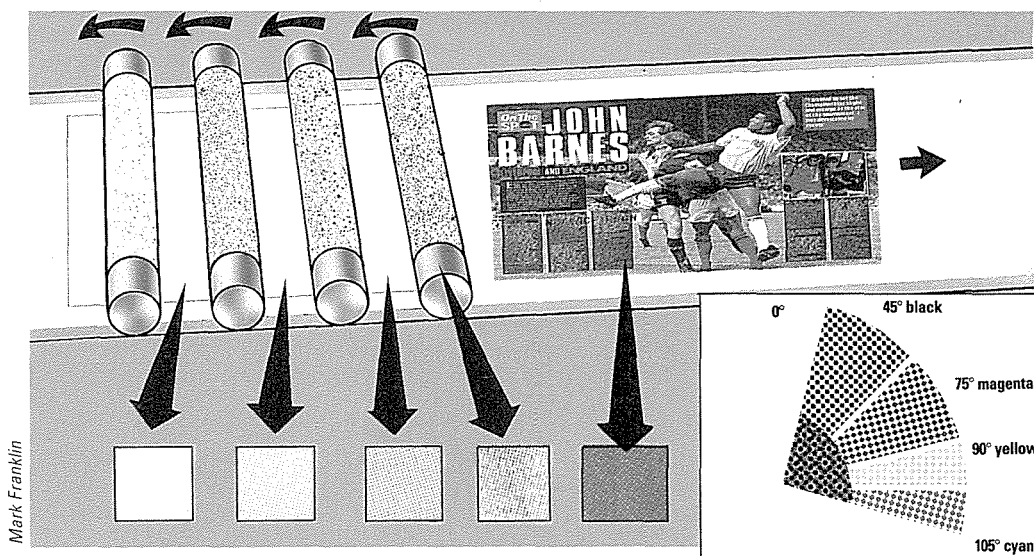
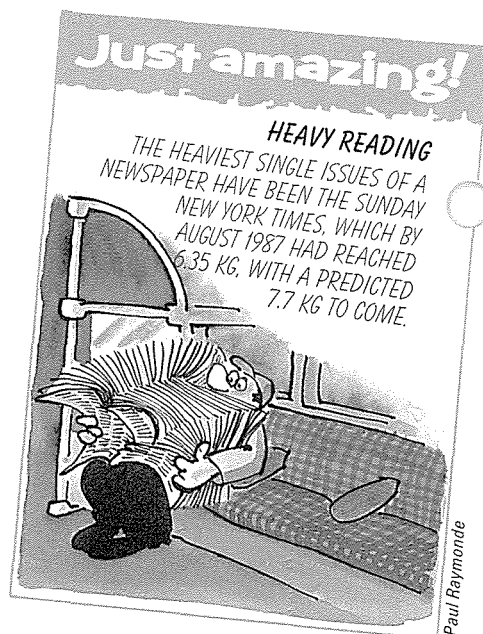
Some printers still use Linotype, but it is quickly giving way to computerized typesetting and printing. Here, the text to be printed is

keyed in at a computer workstation and displayed on a television-like screen. Any changes to the text are easily made at this stage, by the reporter or the editor, with a word processing program.

Electronic printing

The computer is used to select exactly how the edited text will appear on the finished page – the size of letters, the arrangement of the text, and so on. This is continually monitored on a high resolution TV screen. When everything is finalized, the computer sends digital signals to a laser to print the page on to light sensitive film. This film is used to make the final plate.

Computers are also used in the final printing process. They can be used to monitor and adjust the fine tuning required right until the printed page rolls off the press.



Full-colour pictures are usually reproduced in magazines and books using only four colours – yellow, magenta, cyan and black. An electronic scanner first produces four dot patterns representing the yellow, magenta, cyan and black content of each part of the picture. Each of these patterns is recorded as a black image on a sheet of film. These images are used to make printing plates that apply each colour ink in turn to the paper to give the final full-colour picture.

ELECTROSTATIC PRINTING

Photocopiers are also used for printing. Some machines reproduce in colour and even add it where needed. To print, the original is projected on to a drum coated with selenium – a substance that loses its electric charge when light shines on it. The pattern formed on the drum attracts powdered ink, which is then transferred to the printing paper.





Zeta

AudioVisual

WE ARE LIVING IN THE AGE OF information. The large amount of communication, as well as the sophistication of sound and picture reproduction, that can be called up by almost anyone, are all part of a world-wide audio-visual revolution.

Two of the most popular forms of storing and reproducing sound have been on records and tapes.

On the surface of a record, a fine groove spirals in from the edge of the disc to the centre. It is within this groove that sounds are stored as replicas, or an 'analogue', of the original sound waves.

To make a gramophone record, a master disc is first produced from a tape recording of the sounds made

in the studio. A blank, lacquer-coated metal disc is spun on a turntable and a chisel-shaped cutter is lowered on to its surface.

Sound signals from the tape make the cutter vibrate rapidly so that it cuts a wavy track through the lacquer as the disc rotates.

Plating and stamping

The master disc is plated with silver and nickel to form a master shell, which is then peeled from the lacquer. After further plating processes, a metal shell called a stamper is produced. Two different stampers, one for each side of the record, are placed in a record press. The final disc is made by squeezing hot pvc between the stampers and then

Compact disc and video recorders lead the audio-visual revolution in the home. Rapid advances in laser technology and computerization mean that extremely sophisticated equipment can be mass produced and sold at an affordable price.

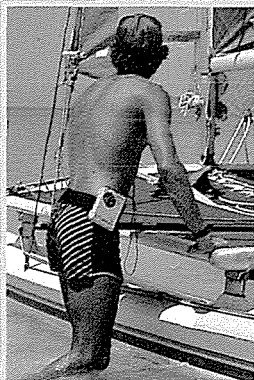
trimming any excess plastic.

Back at home, the disc spins around on the record-player turntable at the same speed as it was recorded — 33, 45, or, rarely, 78 rpm (revolutions per minute). When the needle touches the surface, it slots into the winding groove and begins to vibrate as it traces out the pattern of waves. The tiny to-and-fro move-



PERSONAL STEREO

A portable cassette player can be taken anywhere – even under water, if it is the right model. The basic principles of a conventional cassette player apply, but in miniaturized form. The tape in the cassette is moved along by the capstan. As it passes the playback head, the signals imprinted on the tape are read by the head, amplified and then transmitted to the earphones. Some personal stereo machines can also be used for recording. They have an extra head for erasing used tape and may have a microphone.



ments of the needle are turned into electrical signals by the cartridge. These are then strengthened in the amplifier and fed to loudspeakers.

All on tape

Records give good-quality reproduction but are easily damaged. By comparison, tapes last much longer and can be played in a car or on a machine fastened to the waist.

A tape is basically a long ribbon made of plastic. But on the surface of the plastic, microscopic particles of iron oxide or chromium dioxide have been deposited. When these particles are exposed to magnetic forces, they rearrange themselves into invisible patterns.

To record, the microphone picks up sounds and changes them into electrical signals. These are amplified and fed to the recording head of the tape recorder. The head, a kind of electromagnet, changes the signals into a varying magnetic field. As the tape moves past the head, it is magnetized with a pattern that corresponds to variations in the original sound waves. This magnetic recording is automatically erased if the tape is used to record other sounds at a later date.

Usually, the same head is used for recording and replaying the tape. On replay, the magnetic pattern in the tape produces a varying electric-

al signal in the head, which, after amplification, is fed to the loudspeaker to be turned into sound.

Most tape players today are of the cassette variety, running off tape that is approximately 4 mm wide. Open-reel machines, once common in the home are now found mostly in recording studios. Some studio tape machines can record up to 32 separate sound tracks side by side on a wide tape.

Better by numbers

With their shining silvery surfaces, compact discs, or CDs, provide almost fault-free sound reproduction. This is because they store sounds, not magnetically or by wavy grooves, but in the form of numbers, which are digitally translated into microscopic pits burned into the surface of a disc by a laser beam.

To make a compact disc, the signals from a studio microphone are first changed into numbers (digi-

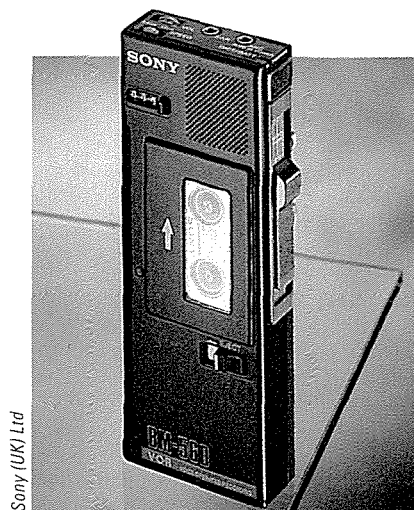
tized). These numbers are then translated into instructions to the laser beam, which etches the surface of the blank rotating master disc accordingly.

As in ordinary disc manufacture, the master disc is used to make stampers that press out the CDs.

In the player, the compact disc spins around over a laser beam.

Sony (UK) Ltd

Steve Latibeaudiere



Sony (UK) Ltd

The talking note pad is a very small form of tape recorder. It takes a micro cassette, but it is not suitable for high quality recording.

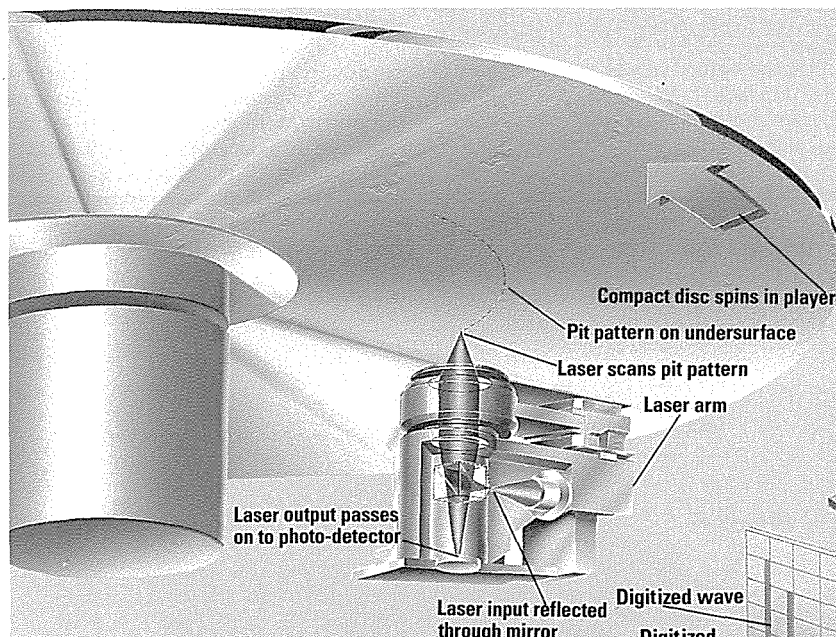


Paul Raymonde



HOW A CD WORKS

As the disc spins in a CD player, a laser beam scans its partly pitted surface. The beam is reflected by a prism or semi-silvered mirror on to the disc. When reflected straight back from a flat part of the disc, the beam passes through to the photo-detector. This changes the flashes of reflected laser light into electrical pulses, which are used to reconstruct the original sound signals. Dust or scratches on a CD have little effect on the amount of light reflected from the surface, so the sound reproduction is free from crackles.

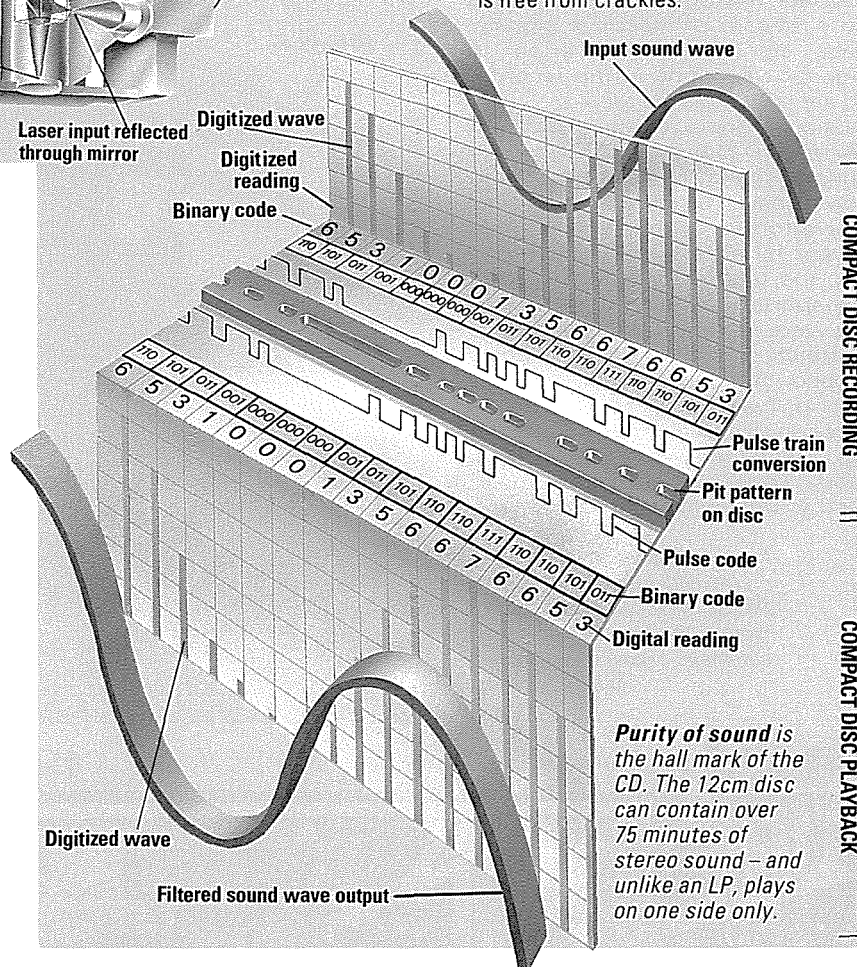


When the beam hits a flat part of the disc, it is reflected on to a device called a photocell, which then gives out a small electrical current. But when the beam strikes a pit on the disc, it is scattered and no current flows from the photocell. The resulting digital signals are changed back into their original, analogue form, amplified and used to produce sounds in the loudspeakers.

Digital audio tape (DAT) is the digital equivalent of ordinary recording tape. Here, the sound is recorded and played back digitally with high quality tape, which records the signals as invisible magnetic patterns. However, digital tapes can only be used on a 'dedicated' (specially designed) machine.

The video invasion

If there has been a revolution in the hi-fi industry, it is nothing compared to what has taken place in the world of video. Video recorders are so popular that around three quarters of homes in Britain now have one. And the video camera has revolutionized security as well as entering the leisure market.



Purity of sound is the hall mark of the CD. The 12cm disc can contain over 75 minutes of stereo sound – and unlike an LP, plays on one side only.

COMPACT DISC RECORDING

COMPACT DISC PLAYBACK

Kee Scott Associates

As video recorders become sleeker, they also include more features. Some record stereo sound, and the remote control can even be used to set the programme timer.



There are video discs, which work on the same principle as CDs, although the picture signals are analogue, but for the present, magnetic tape continues to rule the market. The video cassette recorder (VCR) is simply a compact version of the video tape recorder that has been used in television studios for many years. One lead connects it to the TV aerial and another, to the TV set. This means broadcast signals must pass through the VCR before reaching the television.

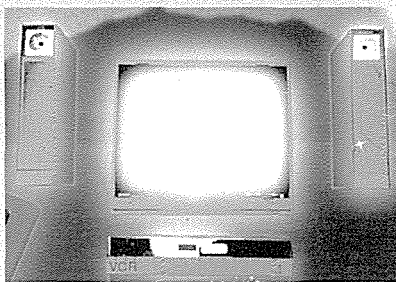
With its own built-in TV tuner and receiver, the VCR can record programmes without the TV set being switched on. It can also record from one channel, while the TV plays a different channel.

The process of video recording is



INTERACTIVE VIDEO

Steven Hunt/Image Bank



A link between videos and computers provides a valuable educational aid. An optical laser disc presents the user with a programme containing a list of options, such as countries. An option is selected, perhaps China, and the computer runs a video on it. Now CDIs (compact disc interactive), where a CD provides audio and visual information, are fast developing for the domestic market.

itself having to move fast.

Some video recordings are not as clear as the original programme. This is because standard tape can accommodate a 'band width' of only half the frequencies transmitted.

Super VHS or Hi8 tape can take on much higher frequencies – even higher than a normal TV set – thanks to the smaller magnetic particles coating it. However, you need a special machine to use them.

basically the same as tape recording. Light and sound from the scene are picked up by the camera and an attached microphone and turned into a stream of electrical signals. These signals are converted to magnetic variations in the recorder and are stored on the tape.

Vision signals contain frequencies much higher than those of sound signals. In order to record such signals, the speed of the tape relative to the recording head must be very high. In early video recorders, the tape moved at the speed of a sports car. But huge reels of tape were needed, and it was liable to stretch or break when suddenly stopped. In modern VCRs, a rapidly rotating head records the vision signals in diagonal strips across the tape, which moves past at slow speed. Thus a high tape-to-head speed is obtained without the tape

The video camera has revolutionized home movie-making. Most cameras feature a microphone, an adjustable lens, automatic exposure and limited editing facilities.



Hitachi (UK) Ltd

INTO THE FUTURE

THE BEST SEAT IN THE HOUSE



▲ Interactive video combined with 3-D viewing on a grand scale could bring any event – real or imagined – into the sitting room of the future.

▲ At the touch of a switch, the viewer could feel himself projected into the action of a movie and experience the sensation of actually participating in the scene.

▲ Or by simply choosing his own camera angles, he could find himself viewing his favourite football team from the 'best seats' in the stadium.

Burrows



FRAUD AND FORGERY



MGM/Kobal Collection

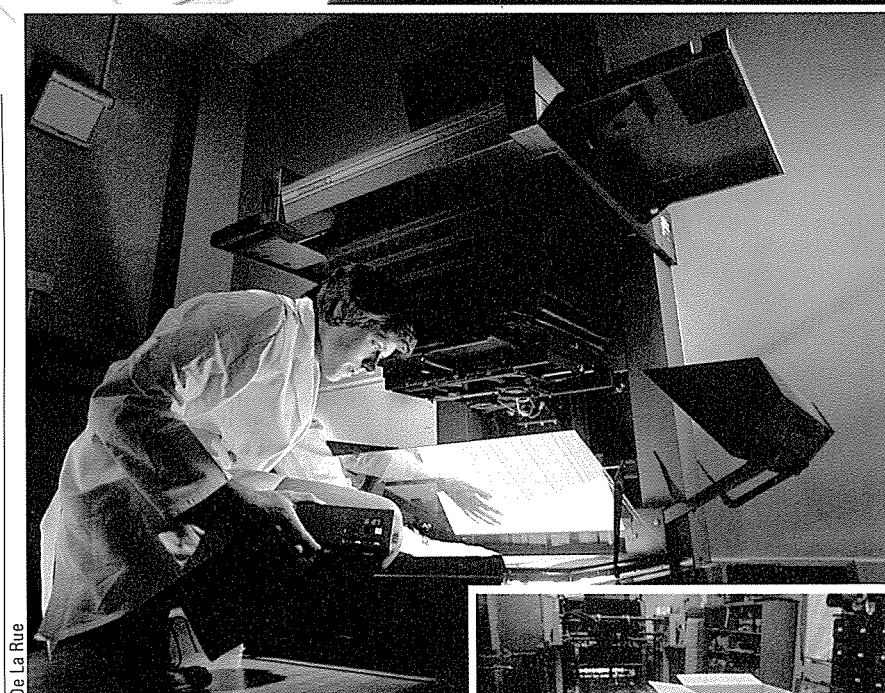
- COMPUTER HACKERS
- FAKE BANKNOTES
- HIGH-TECH TESTS

A SCHOOLBOY COMPUTER whizzkid penetrates the military computers controlling the US missile system and convinces experts there that a World War is about to start.

Fortunately, it all takes place in a movie — *War Games* (above) released in the USA in 1984 and in the UK in 1986. But such fantasies about 'hacking' — as this activity is called — have come close to the truth. In 1985, seven teenagers were found guilty of hacking their way into computer systems controlled by the Pentagon, the US Military High Command headquarters, in Washington.

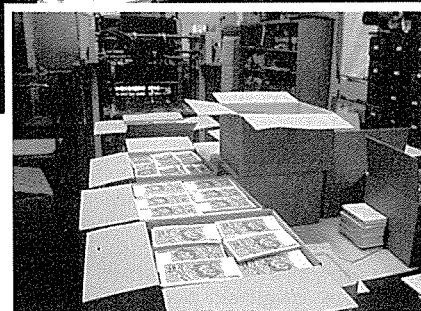
By the time the FBI (Federal Bureau of Investigation) caught up with them, the hackers had access to information that would allow them to alter the position of American weather satellites.

Many computers protect their stored information by insisting that



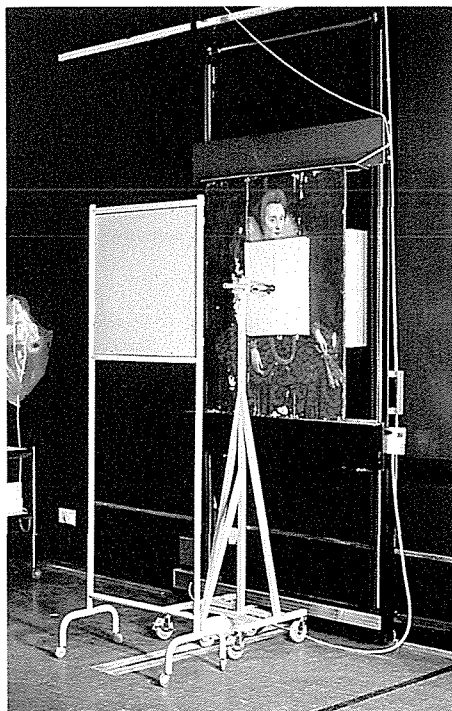
De La Rue

The graphic arts camera is used by more than 85 per cent of the world's banknote counterfeiters. The boxes (inset) contain seized counterfeit French currency with a face value of 70 million francs.



Oliver Boiter/Gamma/Frank Spooner Pictures





Suspect paintings are examined using an X-ray source behind the painting, while a photographic plate is pressed on to the paint. When the plate is developed, fresh paint and any alterations can be spotted.

a password is typed into the machine before access is allowed. Commercial computer networks, such as British Telecom's Prestel, have elaborate protection devices. But even these have fallen before the determined hacker.

While hackers are becoming a serious menace to commercial companies who keep all their records on computer, far more dangerous are employees who use their knowledge of the company's passwords and accounting methods to syphon off cash for themselves.

Computer fraud is merely the more glamorous form of a criminal activity that has been around as long as clever and skilled people have been able to simulate anything valuable, from passports to paintings and perfumes.

Spotting the fake

The most basic weapon in detecting fraud in a document is a sharp eye. Usually an experienced forensic scientist will first look for obvious clues, and then seek the aid of instruments, starting with a low-power microscope.

Most paper is manufactured with a particular watermark — an almost invisible, transparent symbol which can be seen when the paper is held up to the light. The mark is made when the paper is manufactured. It can be imitated using a wooden stamp and olive oil. However, the false imprint has sharper edges than the original, and can be de-

tected using a microscope.

Another way of checking a suspected fraud, such as a faked signature, is by viewing it under ultra-violet light. If the original signature has been removed, the impression it left will show up under the light.

For further investigation, the object, or a small portion of it, is subjected to chemical analysis.

Gamma ray dating

To determine its true age, a sample of an object may be made radioactive. The rate and intensity of gamma rays it emits can then be used to accurately calculate the age.

The disadvantage of this method is that it leaves the sample highly radioactive, and so it must be kept well shielded afterwards to avoid dangerous radiation from it.

Ancient artefacts able to withstand great heat, such as pottery, can be distinguished from fake lookalikes by a method known as thermoluminescence. When the clay is fired to about 600°C, it emits energy in the form of light, which can then be measured to calculate the date of origin of the clay.

Printing money

Banknotes have always attracted the attention of counterfeiters, and modern technology is making it much easier to produce high-quality colour copies of printed material. However, the companies responsible for designing and printing banknotes have introduced various measures to make realistic copies difficult to produce and to make forgeries easy to detect.

Modern banknotes bear intricate designs containing numerous fine lines, originally made in metal by a master engraver. Such fine detail is extremely difficult to copy, even



using the best reproduction equipment. Other security measures include the use of intaglio (sunken) printing to give the notes a characteristic 'feel', special threads incorporated in the paper, the use of watermarks, and the individual number of the notes. Some notes are printed with a fluorescent metallic ink, the appearance of which is impossible to reproduce by normal copying techniques.

Some of the most attractive forgeries have been made by painters accomplished enough to imitate a great master. Their motives are varied, from frustration to resentment against the established art world. If their art does not give them away, their materials do. Paints, pigments and techniques have changed greatly over the years, and sophisticated chemical detection means it is now extremely difficult to cheat the forensic scientist.

THE TURIN SHROUD

The Holy Shroud of Turin — for centuries thought to have covered Christ's body after the Crucifixion — has been revealed as a fake. British scientists, using radio-carbon dating techniques, have shown that the shroud was probably made in the mid-1300s.

Believers in the shroud's link with Christ thought that heat generated by the Resurrection had somehow scorched an image of Christ's body into the material. However, doubts about its authenticity are not new.

As long ago as 1389, a French bishop declared that the image had been 'cunningly depicted' by an artist in order to convince others that it was Christ's shroud. The artist was even said to have confessed to his crime. Nevertheless, many clung to their belief of the shroud's authenticity and, even now, many will probably choose to ignore what the scientists have to say.



Frank Spooner Pictures

COMPUTER-AGE

POLICE SEARCHING FOR THE killer of the Scottish schoolgirl, Susan Maxwell, amassed over 75,000 statements from potential witnesses. The paperwork alone weighed over seven tonnes and architects had to be called in to check whether the floors of the police station were strong enough to support the weight.

Faced with such a mountain of paper, detectives had the greatest difficulty in searching for any kind of common thread, or locating facts when they were needed. When Susan's murder was followed by two further killings, which bore the hallmark of the same person, the police decided that only HOLMES could crack this particular case.

Master detective

HOLMES is not the mythical detective created by Conan Doyle but a computer system – the Home Office Large Major Enquiry System. The one gigabyte capacity (100 million words) of its computer is sufficient to store and digest the vast number of witness statements generated by a major crime enquiry and to assist officers in tracing common themes and patterns.

One of its unique features is free

POLICING

- ☐ COMPUTER DETECTING
- ☐ TRAFFIC CONTROL
- ☐ INTERPOL



Motorway traffic is monitored by computers, enabling the police to minimize delays caused by accidents and get help quickly to injured victims. Their task becomes more and more vital, as traffic volume increases.

text retrieval. Thus, if a witness mentions the fact that he saw a man in a leather jacket near the scene of crime, it is possible at the touch of a button to call up any other statements, from among the thousands collected during the

Radio controlled cars enable police to be on the spot whenever trouble arises – their radios allow them instant access to the Police National Computer.

course of enquiries, that also mention men in leather jackets. Another aspect of the system is the exceptional reporting feature that alerts the operator when a witness mentions a person who has been linked to the crime by another witness.

Police investigating the Yorkshire Ripper murders could have made good use of this feature when different officers managed to interview the Ripper, Peter Sutcliffe, on nine separate occasions without

Metropolitan Police



the common pattern being noticed. HOLMES is expensive, and is used for major crime. More routine policing relies on another computerized communication system – the Police National Computer (PNC).

Information store

The PNC is housed in a special high security building at Hendon, near London, and currently consists of three central processing computers, with a capacity of over 12 gigabytes – more than 1,000 million words. There are plans to increase this number substantially.

The information stored on PNC includes:

- records of 36 million vehicles and their owners
- stolen and suspect vehicles
- criminals' names and their known aliases
- descriptions of criminals and their fingerprints
- names of disqualified drivers
- wanted or missing persons.

Police in the regional forces keep in touch with PNC via some 1,300 computer terminals in local stations, which flash information back on a video screen. These facilities are backed up by nearly 200 data-printers, which provide a more permanent written record of any information requested. Officers on the beat carry personal radios that give them access to PNC's memory.

Instant check

The most frequent use of PNC by officers on the beat is for checking the owners of suspect vehicles. These amount to over 20 million in a year, or around two thirds of all requests for information.



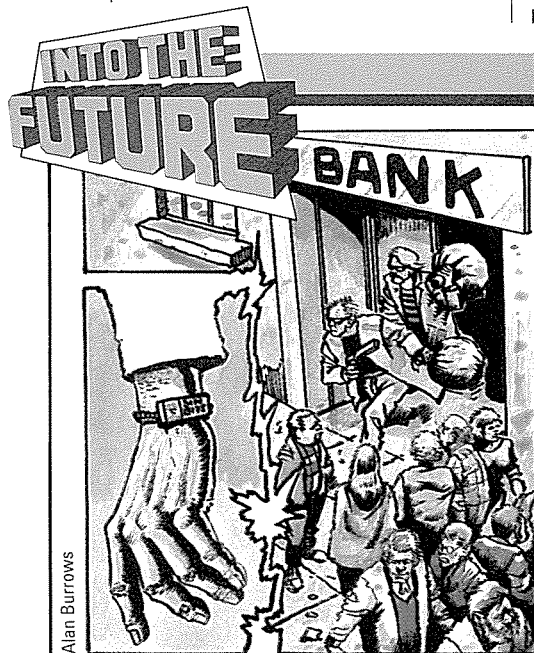
Interpol provides police throughout the world with a computer network that helps track down criminals, such as international gun-runners. In 1987, the Eksund, an IRA arms ship on course from Libya to Ireland, was seized off the coast of France from information fed in by the British police.

Other major uses for the system are checking on the identity of suspects and possible missing persons. Each of these services are used about nine million times a year. Electronic links are gradually being established between PNC and

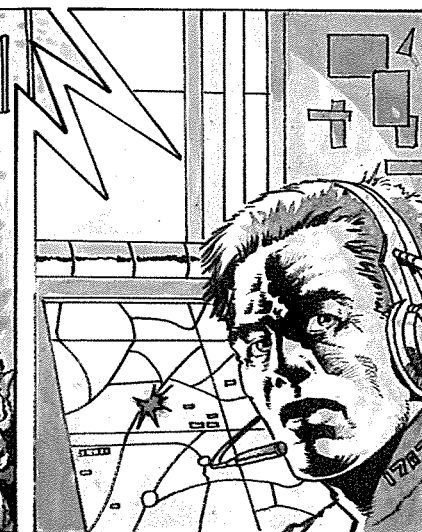
various regional memory banks or 'databases'. This means that if an officer requires more information about a suspect, he or she can be directed elsewhere on the electronic network.

International policing

For policing worldwide, an international computer link is provided by Interpol. Interpol helps police to gather information as and when requested. However, a new 'gathering and sharing' agency, Europol, is now being set up to provide police throughout Europe with a readily available bank of information on computer.



▲ The time may come when all criminals have their own computerized identity bracelets, which will allow the police to monitor their every movement.



▲ As soon as the alarm is raised when a crime is committed, the police will be able to isolate all the identity bracelets in the area and check criminal records.



▲ Any suspected criminals can very easily be tracked down – no matter where they are. The police can then pick them up and bring them in for interrogation.

GUNS BALLISTICS AND

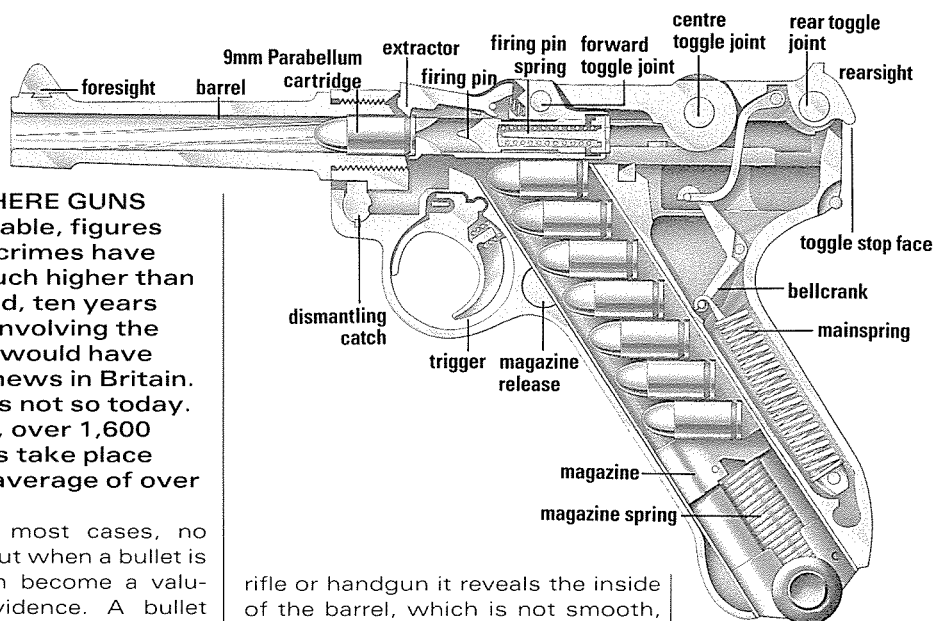


Gamma/Frank Spooner Pictures

IN THE USA, WHERE GUNS are readily available, figures for gun-related crimes have always been much higher than in Europe. Indeed, ten years ago, any crime involving the use of firearms would have made headline news in Britain. Unhappily, this is not so today. In London alone, over 1,600 armed robberies take place each year – an average of over four each day.

Fortunately, in most cases, no weapon is fired. But when a bullet is discharged, it can become a valuable piece of evidence. A bullet carries on it marks as unique to the weapon which fired it as the human fingerprint.

To determine whether a bullet came from a particular gun, police experts in ballistics (the science of how projectiles travel) use a special instrument called a helixometer. This consists of a fine tube with a light and magnifying lens at one end. When placed in the barrel of a



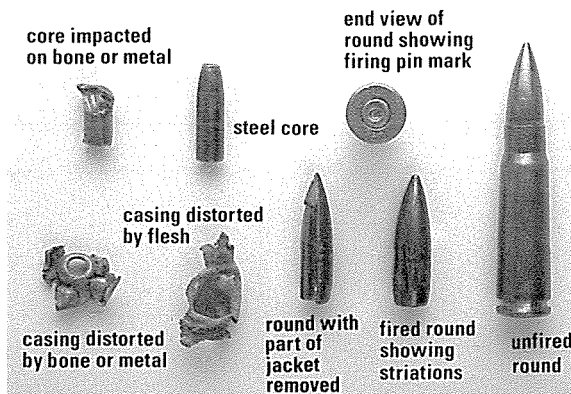
rifle or handgun it reveals the inside of the barrel, which is not smooth, but cut with a series of spiral grooves known as rifling.

A bullet will travel further and straighter if it is spinning. The spirals in the barrel of the gun are designed to impart twist to a bullet in order to achieve that spinning effect. The raised parts of the spirals, called lands, are separated from each other by grooves. The internal diameter of the barrel is known as

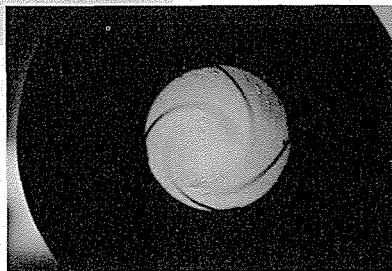
A Luger ready for firing – its firing pin cocked. The extractor, forced up by the chambered cartridge, shows the gun is loaded. The spent cartridge is ejected as the firing pin retracts.



IDENTIFICATION MARKS



An undamaged bullet can be examined by ballistics experts to compare the striations (marks) on it with the rifling on the inside of the gun barrel. When a bullet hits its target, it disintegrates in different ways, depending on whether it hits soft flesh or bone.



In the ballistics laboratory, experts use three different types of microscope. A comparison microscope is used to compare two bullets for corresponding marks, a fibre optic bore microscope for viewing rifling details, and a measuring microscope for calculating rifling characteristics on fired bullets.

the calibre and determines the size of ammunition fired.

Bullets are always slightly larger than the calibre of the gun that fires them. This ensures that, as the bullet travels down the barrel, the fit is tight and none of the power of the propellant gas behind the bullet is lost through leakage.

As the rotating bullet is forced down the barrel, the rifling scars the bullet in characteristic ways. So characteristic are these marks, or striations, that an expert can immediately deduce what type of gun fired which bullet.

The individuality of guns does not

end with types of weapon. The machine tools used in the factories that introduce the rifling on gun barrels are sharpened frequently. Every time this is done, it introduces a different pattern of microscopic marks in the barrel of a given weapon and these are impressed on every bullet fired from it.

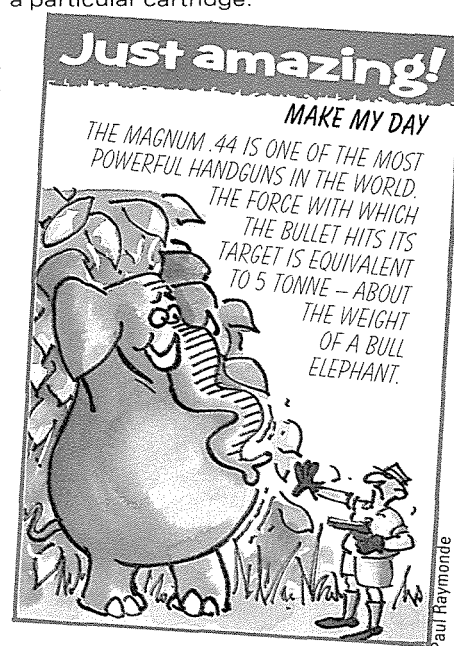
Police can, therefore, prove whether a particular gun fired a bullet recovered from the scene of a crime by taking the gun and firing a second bullet, which can be compared with the first. The striations on the two bullets can then be compared using a comparison

microscope. If the marks match perfectly, both bullets came from the same weapon.

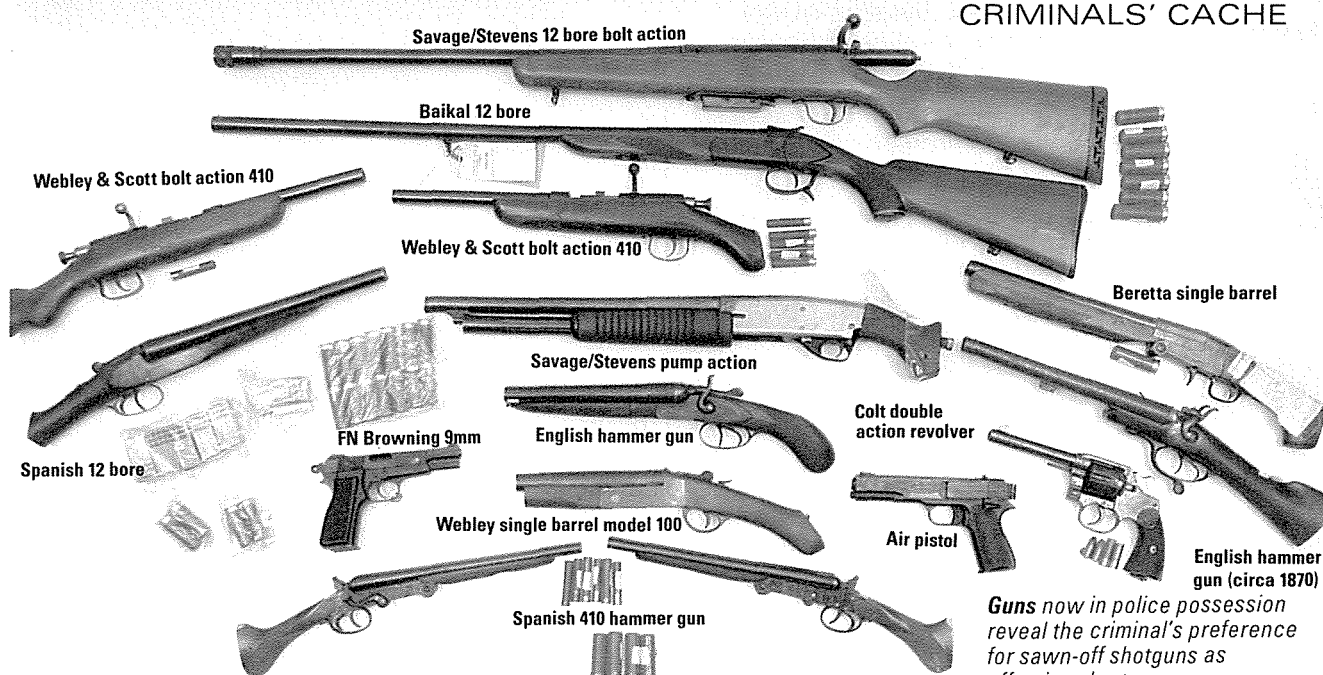
There is one kind of weapon that has an unrifled barrel — the smooth-bored shotgun. Criminals sometimes saw off the barrel and cut down the wooden handle, or 'stock', to produce a sawn-off shotgun — easily concealed and deadly.

Instead of bullets, shotguns fire a mass of tiny lead pellets. Over 2,000 of these are packed into each shotgun cartridge. Although the pellets do not reveal which gun they come from, the empty cartridge case carries an important clue. Its brass base bears the mark of the gun's firing pin. Each gun leaves a slightly different mark on its cartridges, so it is easy to determine whether or not a particular gun fired a particular cartridge.

Hicks Photographic Services

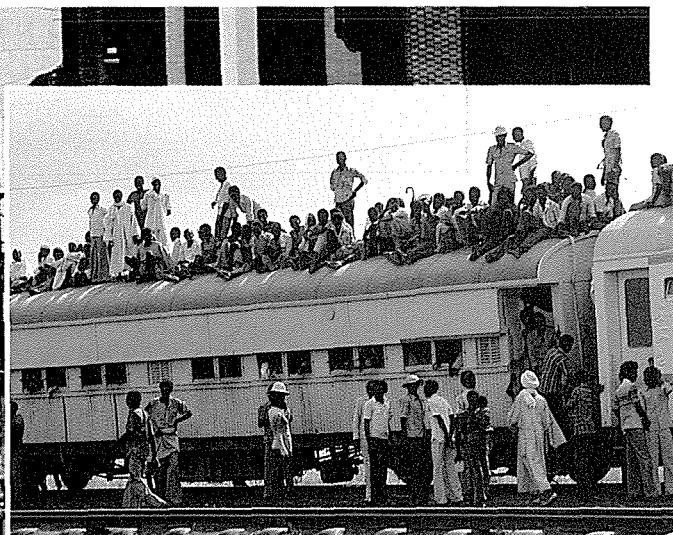
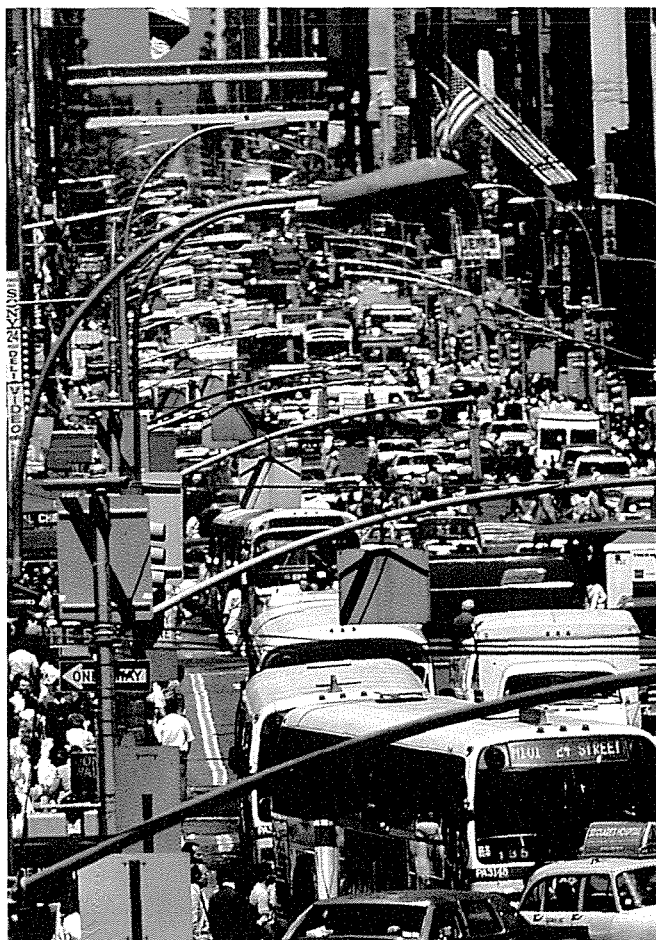


CRIMINALS' CACHE



Guns now in police possession reveal the criminal's preference for sawn-off shotguns as effective short-range weapons.

GETTING ABOUT TOWN



Hutchison Library



Zeta

MILLIONS LIVE IN CITIES ALL over the world and millions more pour into them every day. The congestion and pollution that result put traffic and public transport problems high on the list of a city's priorities.

One way of discouraging heavy traffic is to turn busy parts of a city, such as shopping centres, into pedestrian-only precincts.

Another way to lessen pollution from exhaust fumes is to encourage bicycles by providing ample bicycle-

only lanes. Amsterdam has long given precedence to pedal power, but in less affluent Beijing — the capital of the most populous country, China — bicycles are all that the majority can afford, and the odd car is usually completely swamped in huge bicycle jams.

No matter how many more roads are built to cope with increasing traffic, it has a knack of multiplying to fill the available space. The answer lies, therefore, in better traffic management. This includes highly sophisticated traffic control

Rush hour in New York can be a rough ride for commuters by car. Public transport can move large numbers of people more efficiently. The Sudanese train (inset) demonstrates that just over 500 passenger cars are not enough to provide an efficient railway service.

systems, such as UTC — Urban Traffic Control — which uses the latest microchip technology direct from a central computer.

Computerized traffic

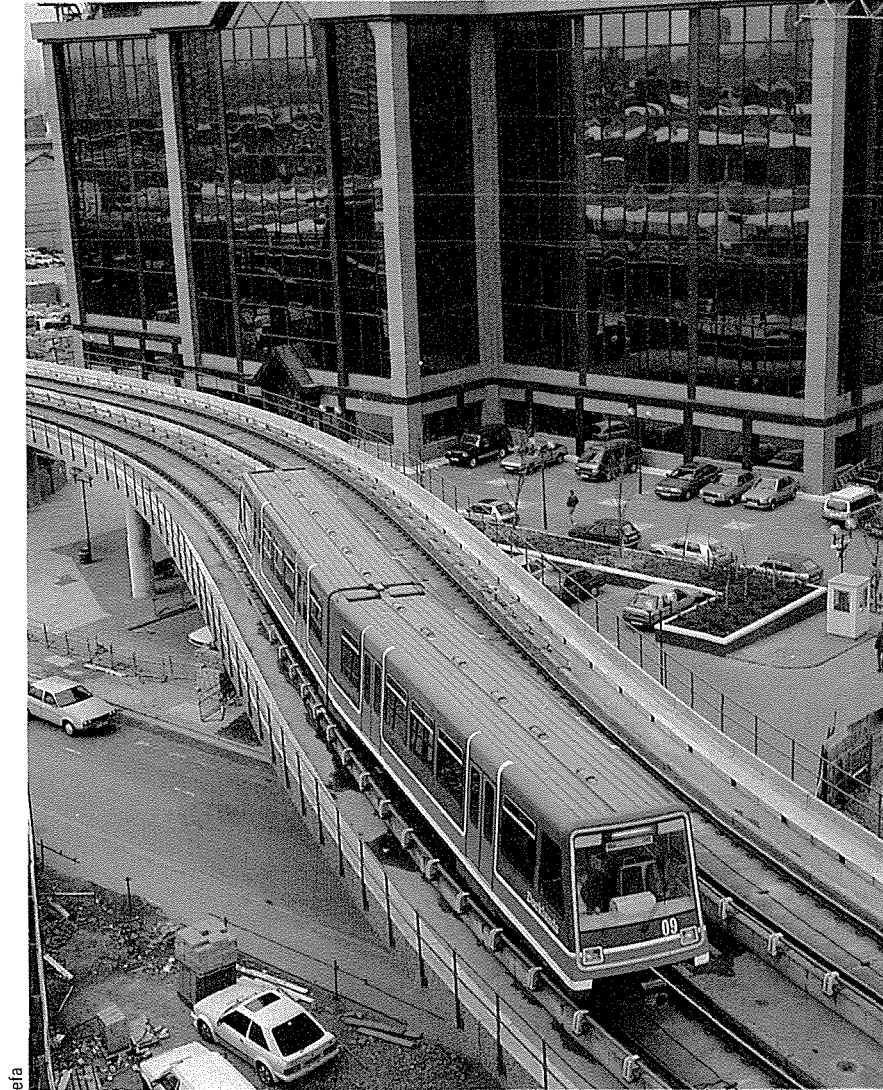
Programs, such as TRANSYT and SCOOP, vary traffic signal rotation according to the flow of traffic. This is monitored by vehicle-detector induction loops embedded under the road near intersections. Journey time has been reduced by nearly 20 per cent, and fuel consumption about 15 per cent because of them.

Special lanes for buses, sometimes in both directions in the centre of a major urban thoroughway, as in Washington DC, allow many more people to travel much faster than in individual motor cars. Not



A computerized map, such as Digiplan in Lyons, France, automatically shows the best route for individual passengers to any destination within the city. A very simple route planner is available in a number of London underground stations.





Zefa

only are buses monitored along special bus lanes, again, by induction detector loops under the road, but many are equipped with two-way radio. This keeps both driver and the central control in touch with each other about existing condi-

A fully automated shuttle service, the Docklands Light Railway, is London's latest addition to public transport. It runs completely on overhead tracks.

Reflecting luxury of a bygone era, the Moscow underground carries over 2,500 million passengers each year.

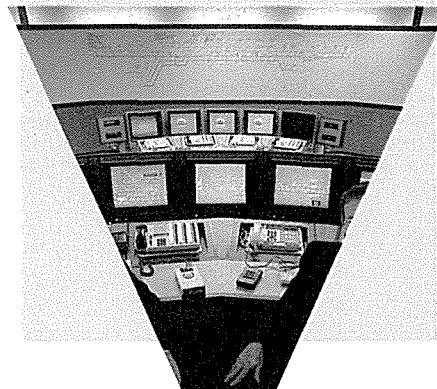
tions on the road, so that the best route and the frequency of buses can be monitored.

Inductive loops can also be used to drive the bus. In Sweden, they steer the bus accurately to a bus stop. When the bus approaches the loop, the driver switches to auto-control and the bus aligns and halts perfectly.

Specially allocated lanes for public transport are difficult to maintain, but vehicles on a permanent track, especially if it is banked off, always have right of way. This is the great advantage of tramways and trolley-

UNDERGROUND HQ

Computers help run the world's largest underground system in London, as communication is vital to ensure a smoothly run network. Up-to-the-minute information, relayed instantly between stations down the line, helps to monitor the frequency of the trains and keep waiting passengers informed.



Barry Lewis/Network

buses. Many cities are returning to modern versions of the tram. The cost of re-introducing trams is much less than for excavating new tunnels for an underground system.



Making tracks

Trams and trolleybuses require overhead cables to supply the power, and tracks for wheel guidance. Tracks can be elevated, partly sunk or tunnelled. The overhead cables are not always necessary as some trams or trolleybuses carry batteries which can be charged from the cables earlier in the journey to pro-

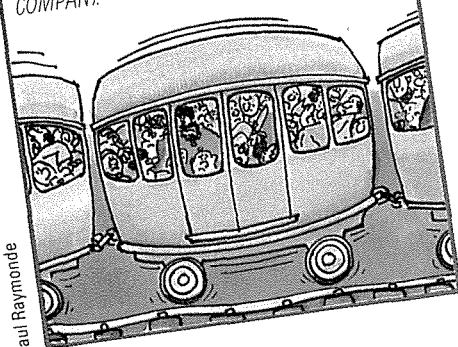


Hutchinson Library

Just amazing!

RUSSIAN ROULETTE

RIDING AROUND ON THE MOSCOW UNDERGROUND IS NOT FOR THE CLAUSTROPHOBIC. EVERY DAY, SEVEN MILLION PASSENGERS KEEP EACH OTHER COMPANY.



Paul Raymond



TUBE DISASTER

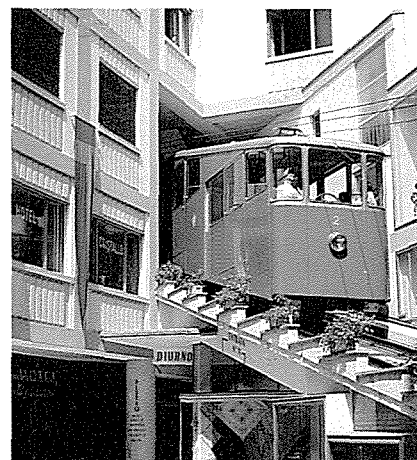
Gamma/Frank Spooner Pictures

Millions travel on underground trains daily and accidents are rare. Safety depends greatly on stringent cleaning and good communications at all levels. A cigarette butt thrown on an escalator at Kings Cross station, London, set fire in November 1987 to uncleared grease and rubbish below. As a result of the fire, cigarette smoking was banned in all stations and 104 new safety procedures were instituted.



Hutchinson Library

The Bay Area Rapid Transit of San Francisco (BART) runs underwater for 6 km along the bay and is unstaffed. The entire system is operated by just two supervisors in a central control room and by computers at each of the stations en route.



J. Allan Cash

automatically — but otherwise, is left to be driven freely by the driver.

Tracks running through tunnels under a busy city provide one of the heaviest used networks of urban public transport. Free from overhead traffic jams, each underground train has unimpeded right of way within its own tunnel. In London, where the first electric underground train ran in 1890, more than two million people travel on it each day.

Underground trains differ in carriage, shape and style in different cities, but the basic principles of

A funicular riding high is one way of getting about in a steeply terraced town. A form of cable car, funiculars can negotiate gradients very efficiently. The cars are merely carriages, as the cables they run on are pulled by a stationary engine.

locomotion are the same. Electric power supplied along the tracks is picked up by the driving or traction carriages at the front and the rear of the trains.

The power is taken either directly

from the National Grid or from the transport organization's own generating stations. Varying degrees of automation are available — from automatic door closing systems and trains without guards, to fully

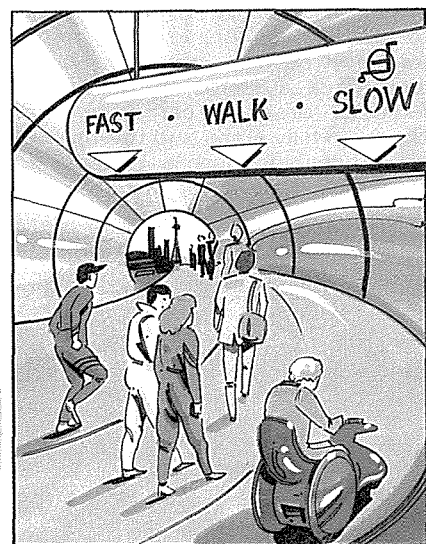
INTO THE FUTURE



▲ Passengers on public monorails could have individual free carriages detached to run as taxis to fixed destinations along the track.



▲ Electrically driven cars would be recharged at self-service 'filling' stations. Credit cards could be used to operate the terminals.



▲ Moving walkways used for long distance strolls would have three lane tracks at different speeds to avoid accidents.

Joe Lawrence

TRAVELLING TOMORROW

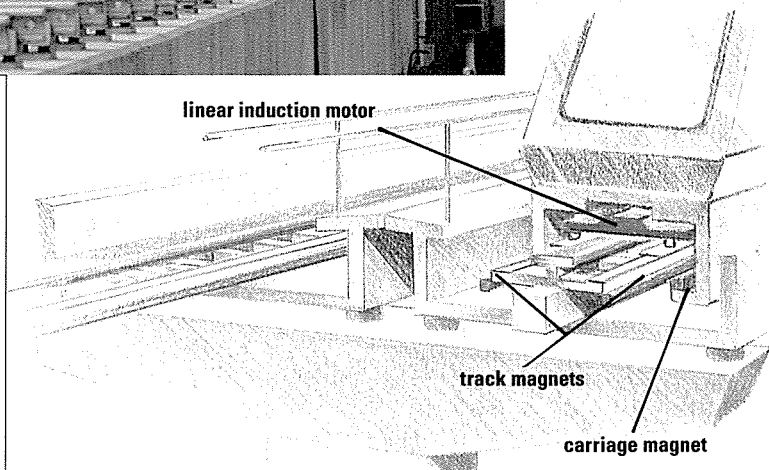


Gamma/Frank Spooner Pictures



The maglev that runs at Birmingham airport (left) operates on the principle of unlike poles attracting each other. This is known as EMS, or electromagnetic suspension. Permanent magnets in the track face downwards, while electromagnets under the vehicle bracket the tracks and face upwards. When the electromagnets are energized, they are attracted towards the track magnets. Special control systems keep train and track 15mm apart, regardless of the load carried.

The Japanese run a maglev – a train kept above the tracks by magnetic levitation – on the principle that like magnetic poles repel each other. This is known as EDS, or electrodynamic suspension. Permanent magnets on the underside of the carriage generate a current as they pass over coils in the track. The current magnetizes the core of the coil to the same polarity as the vehicle magnets, and the resulting repulsive force levitates the vehicle. Another set of magnets and coils generates the electricity as the train moves along. Thus, only a part of the track is electrified at a time.



John Hutchinson

computerized trains which run without drivers.

But underground systems are horrendously expensive to construct. That is why many cities opt to supplement their existing public transport network with more overland track systems, such as the funicular or cable car. It is used chiefly in hilly areas and towns with steep inclines, and is cheaper to build than roads or railways.

But cable cars can carry only a

limited number of passengers as the cable track can transport only two cars at a time. Usually, cable cars are run in tandem in opposite directions – one being pulled up by the other travelling down. The track is just like a railway track except for the cable running down the centre.



Poles apart

Of all various forms of public transport a city can provide, the most innovative is the train that virtually

'flies' over the track by magnetic levitation – the maglev. Because it has no moving parts, there is no wear and tear from friction and the ride is smooth and silent.

Maglev becomes increasingly more efficient with the advances made in superconductors. At an extremely low temperature, a superconductor provides almost no resistance to an electric current passing through it. This allows the current to flow almost permanently, with very little wastage. Because of superconductors, very strong electromagnets in the rail and the train can be made to attract or repel each other with such force that a gap of approximately 15mm can separate the train from the track.

Maglevs, at present, are used only for short journeys, but they can travel at up to 504 km/h.

Helicopter travel is increasing in popularity as roads become more congested. In a densely populated city such as London, helicopters are widely used by the police to survey traffic conditions or to help with crowd control.

Aviation Picture Library



EFFLUENT DISPOSAL

SEWER NETWORKS

CLEANING UP

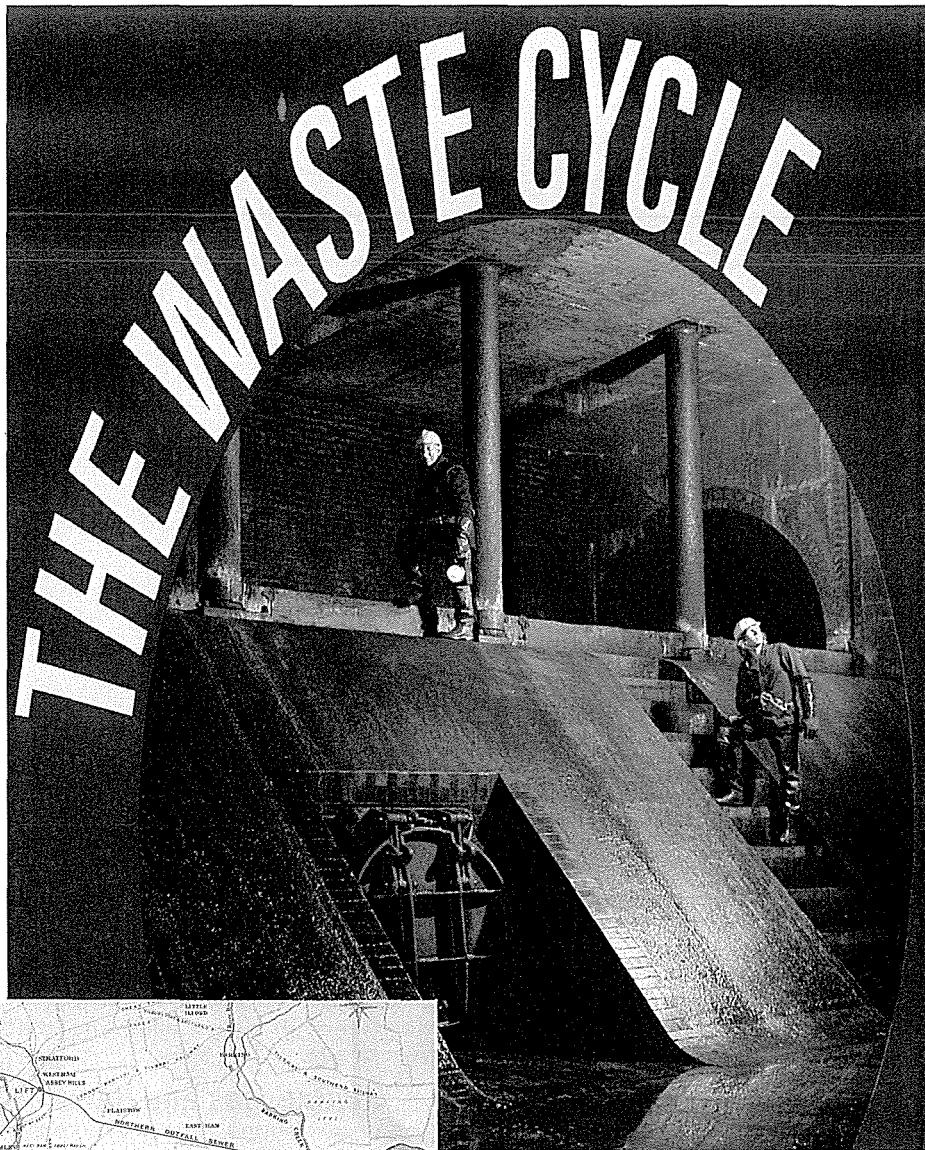
YOU ARE THIRSTY. YOUR hands are dirty. You turn the tap on, out comes water – however much you use, there is always more whenever you want it. And that's a modern-day miracle, only to be seen in the developed world.

The average Londoner uses over 150 litres of water a day, washing, drinking and cooking. But once used, the waste water has to be collected, cleaned and returned to the river or sea in a state fit to be drunk so that the cycle can start over again.



Sewage works

The waste water leaves each house in an underground sewer, which joins larger and larger ones until they all meet the main trunk sewers. The largest sewers are the size of underground railway tunnels and carry huge quantities of rainwater. Having been in place for more than 100 years, many of London's sewers are in poor condition, and the city faces a crisis as more and more collapse under the weight of traffic



Thames Water

Working underground in one of London's trunk sewers. These Victorian tunnels were not designed to cope with either the volume of 1990s sewage or the vibrations caused by heavy traffic, and are in severe need of replacement.

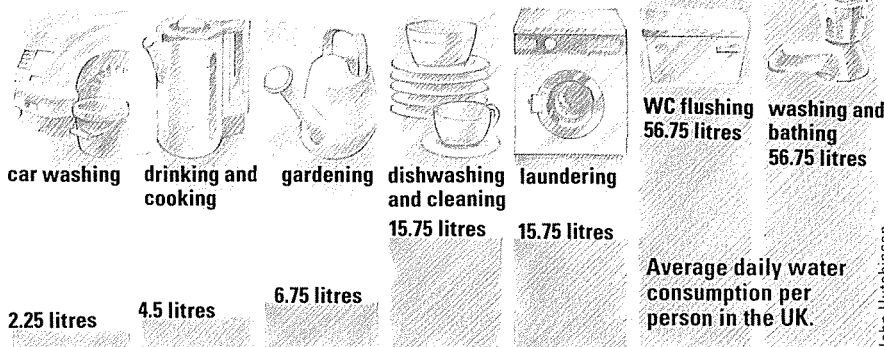
London's sewer network, 1865. Nearly all the main trunk sewers running east to west are still in operation today.

DOMESTIC CONSUMPTION

on the streets above.

At the sewage works, the first job is to remove rags, wood and floating objects which would otherwise damage the pumps and machinery. Raw sewage is passed through screens of metal bars spaced close together. These trap large objects which are then raked off. Those that can be broken down are torn into small pieces and mixed back into the sewage. The rest is burned or buried in landfill sites.

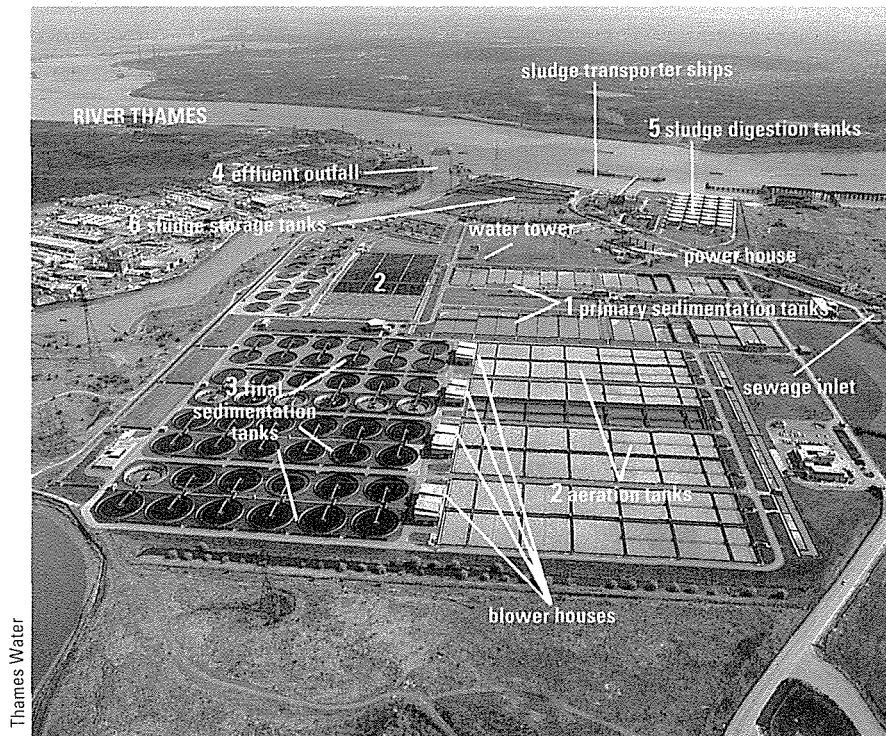
The next job is to remove as



Average daily water consumption per person in the UK.

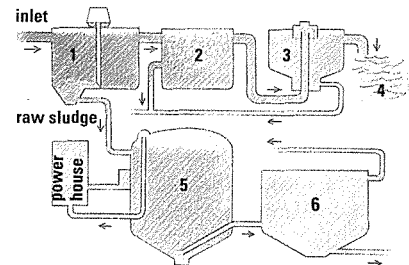
John Hutchinson





Grit is first removed from the raw sewage, which is then allowed to settle in the primary sedimentation tanks (1). In the aeration tanks (2), air is bubbled through the effluent to encourage bacteria digestion. The separated liquid settles (3), before being pumped into the river (4) as 96 per cent pure water.

Raw sludge is drawn off from the primary sedimentation tanks (1), and then digested in the primary sludge digestion tanks (5). The gas given off is then fed back into the power house. After four weeks, the sludge is passed to a secondary tank (6), before finally being dumped on land or at sea.



John Hutchinson

much of the solid matter as possible. The sewage is poured into large primary sedimentation tanks where the solids settle to the bottom. This crude sludge is swept into a hopper by electrically driven scrapers and pumped into a separate sludge digestion plant.

The remaining liquid — called primary effluent — is fed into the secondary treatment plant. Here, bacteria are added which feed on the waste matter in the sewage and digest it into water and gas. To function, the bacteria need a lot of oxygen. One way of providing this is by spraying the sewage on to a bed of gravel. As it passes through the gravel, it picks up oxygen from the air trapped between the particles. Another method passes compressed air into the effluent through special porous tiles called diffusers. These have small holes in them so

that the air flows into the effluent as very small bubbles.

It takes about eight hours to digest most of the impurities. The sewage is then simply water that is clean enough to go back into the river or sea.



Sludge, gas and liquor

The crude sludge from the primary sedimentation tanks is pumped into the digestion tanks where bacteria are again used to digest the unpleasant and smelly material. In the process, sludge gas is given off containing methane which is burnt to power generators, thus producing all the electricity needed to power the sewage works.

After three or four weeks, all the sludge gas has been collected and the sludge is passed into open secondary digestion tanks. There, the thicker sludge settles to the

bottom and the water — or liquor — remains at the top.

The thicker digested sludge can then be used on the land as a soil conditioner once the water has been removed. Any surplus is taken by ship and dumped out at sea, where it provides food for algae, the first link in the marine food chain.

This process of continually recycling all the side-products during purification ensures a degree of stability in the environment, since nothing is dumped as rubbish. Very few chemicals are added in the purification process, and yet most of the industrial wastes present in the sewage can be broken down by naturally occurring bacteria, without help from Man.

Just amazing!

DOWN THE DRAIN

IN LONDON, OVER 3 BILLION LITRES OF SEWAGE ARE GENERATED EVERY DAY. THAT'S AROUND 365 LITRES FOR EVERY MAN, WOMAN AND CHILD LIVING IN THE CITY.



A shanty-town in Manila, capital of the Philippines. With no true sanitation, the toilet-shacks overhang the river: 'flushing' involves dumping the raw sewage directly into the water below. A modern tower-block oversees the slum river.



Sally & Richard Greenhill



XEROXING LIFE

FROZEN FUTURES

PLASTIC
BODIES

CLONE ZONES

FLASHES OF LIGHTNING AND mad scientists cackling with evil glee may be the stuff of movies, but human and animal embryos are now being fertilized and modified in laboratories and operating theatres all over the world.

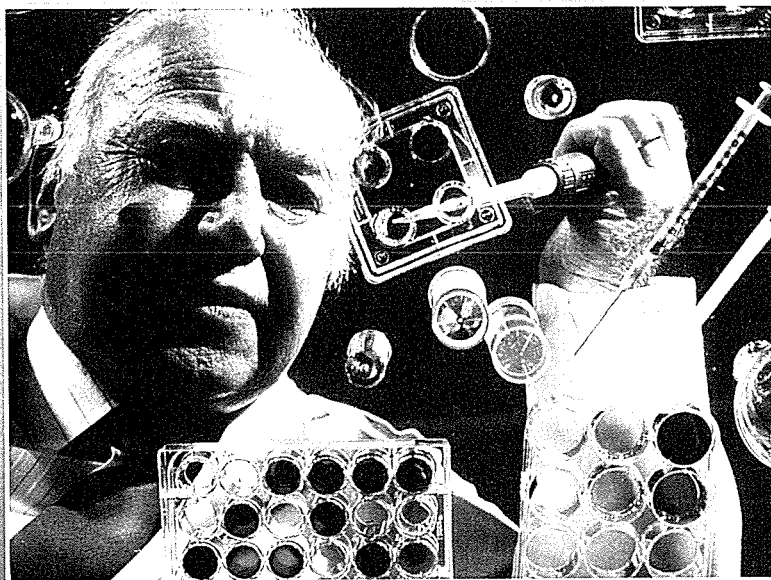
A chicken was the first warm-blooded creature to be developed fully in the laboratory. It was part of an experiment to manipulate live-stock genes by injecting foreign DNA into single-cell embryos. The injected cells are nurtured in a solution of egg-white and salt at controlled temperatures inside a series of empty eggshells. Because chickens have thousands of offspring, it could be possible to create a strain of 'superchickens', starting with genetically-engineered birds, who would then go on to produce generations of offspring naturally. All these offspring would then pass on their 'improved' genetic information to their descendants.

Genetic engineering

Men have been experimenting with animals for centuries, trying to produce superior livestock. Artificial insemination is used to improve

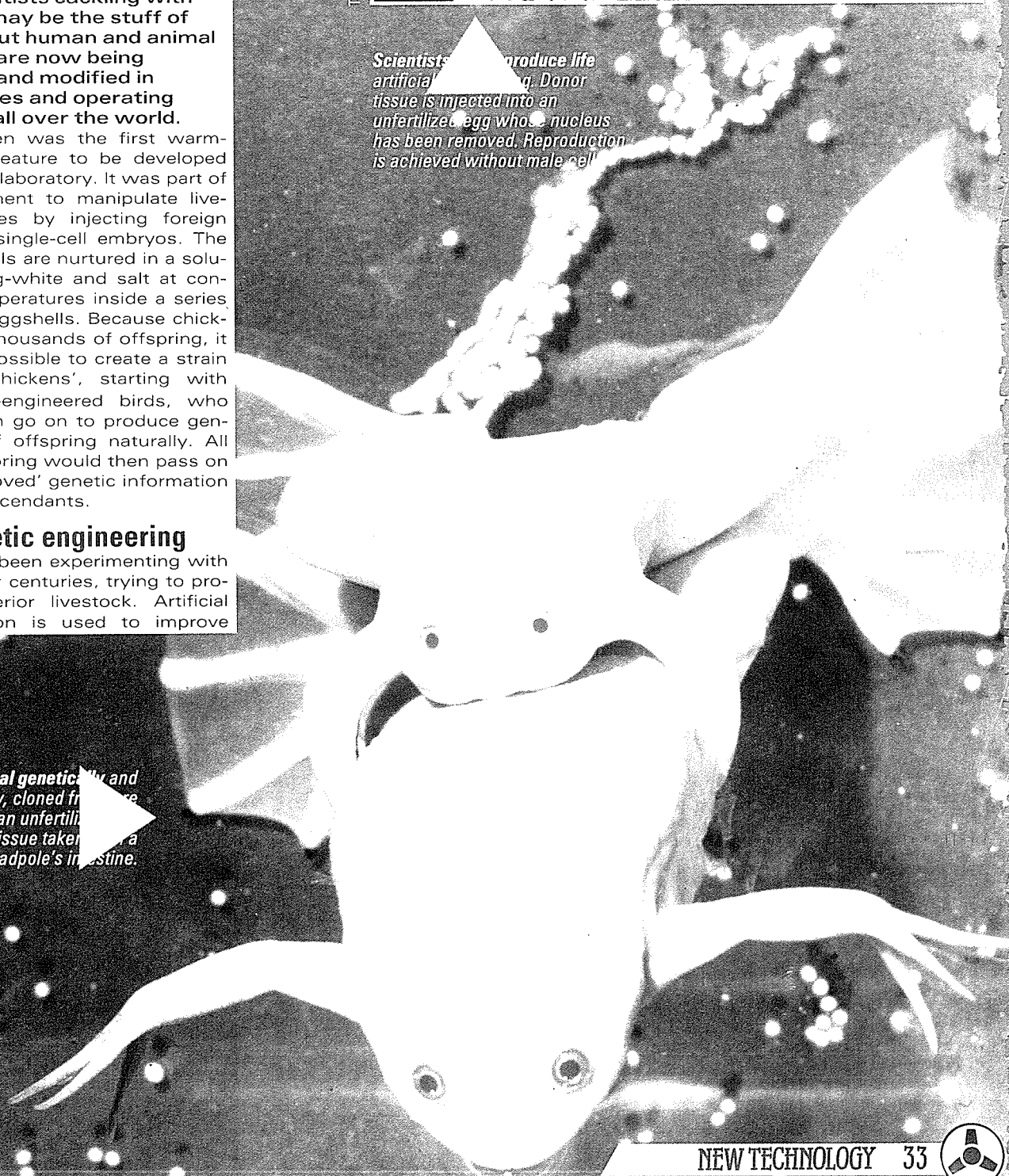
Derek B. Hall

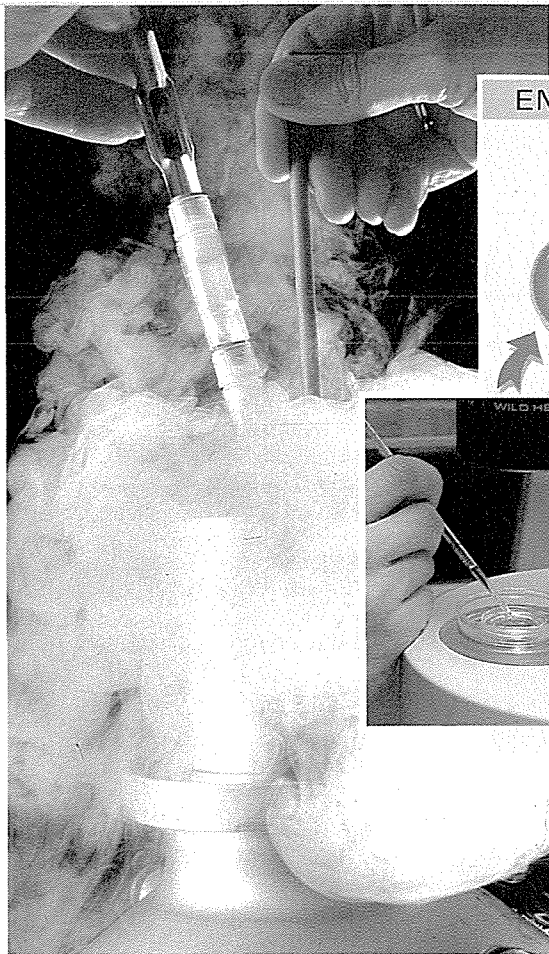
Identical genetically and physically, cloned frogs are made from an unfertilized egg and donor tissue taken from a tadpole's intestine.



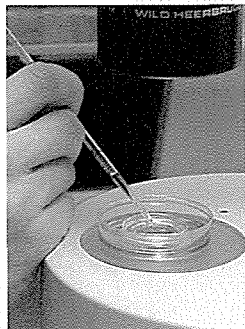
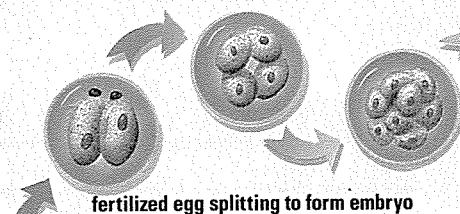
Topham

Scientists produce life artificially using donor tissue is injected into an unfertilized egg whose nucleus has been removed. Reproduction is achieved without male cell





EMBRYOS FORMED IN A JAR



Many infertile parents have found they can now hope for a baby thanks to *in vitro* fertilization, or test tube babies. To achieve this, the surgeon removes an egg from the woman's body and fertilizes it with the man's sperm in the laboratory (left). The fertilized egg then subdivides (above). At about this stage, the surgeon introduces the budding embryo into the lining of the woman's uterus (top

embryo developing into foetus

right). Here, it will continue to develop into a healthy foetus (above). Sometimes, it is necessary to freeze the embryo until the woman's uterus is ready to receive it. At the right time, the embryo is thawed and then inserted into the uterus.

Chris Lyon

Sperm banks store frozen sperm from donors – some even specialize in genius donors. The sperm is used for artificial insemination, and new babies can be made without the parents ever meeting.

herds and flocks with sperm from champion stud animals. Embryo-transplanting enables breeders to obtain first-class stock without buying enormously expensive adult animals.

Cattlemen have introduced high-yielding, disease-resistant cattle from the USA to Africa, by taking large numbers of fertilized eggs and implanting them in the wombs of rabbits. The cattle embryos can survive in the rabbits' wombs for up to eight days. It takes no longer than a couple of days to fly the rabbits to Africa and the cattle station. There, veterinary surgeons transfer the embryos from the rabbits into the wombs of cows.

Genetic engineers work on producing superior animals and plants by taking genetic material from the cells of one strain or species, and adding it to the growing cell-material of a different type.

In animals, donor material has to be introduced into a female egg. With plants, however, it is much simpler. In the right conditions, any single plant cell can be manipulated to produce a whole plant. Agriculturalists can clone plants, producing hundreds or even thousands of new plants, which are genetically identical, all from the same piece of material.



Cloning plants

First, the scientist removes cell material, then he grows it in a rich mixture of hormones and nutrients. The cells divide and redivide, pro-

ducing a mass of plant material called a *callus*. The *callus* will keep growing while the scientist cuts it up repeatedly. Each division, with the proper care, turns into an embryo plant.

All the embryo plants are identical clones of the original plant, all containing identical genes, all programmed to do the same thing at the same time. In identical conditions, the cloned plants will all grow at the same speed, have the same number of leaves and flowers, and all flower and fruit almost simultaneously. This enables oil-palm farmers, for example, to harvest all the palm nuts at the same time, instead of waiting while some ripen.

Cloning raises questions about the limits to which man should go in his attempts to improve on nature or play at God. Researchers have succeeded in cloning both frogs

A 'geep' by any name is a pathetic misfit. This specimen, created from the cells of an embryo sheep and goat, raises serious ethical questions about creating life in the laboratory.



Topham

Just amazing!

LIFE EVERLASTING

DRACULA MAY LIVE IN FICTION. BUT IF CRYOGENICS AND CLONING WERE COMBINED, DEEP FROZEN CELLS FROM OUR BODIES COULD BE USED TO CLONE OURSELVES – LONG AFTER DEATH.

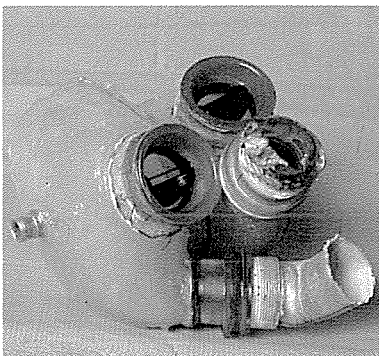


Paul Raymonde





Hank Morgan/SPL



Rex Features

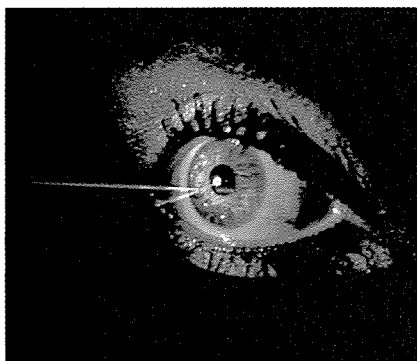
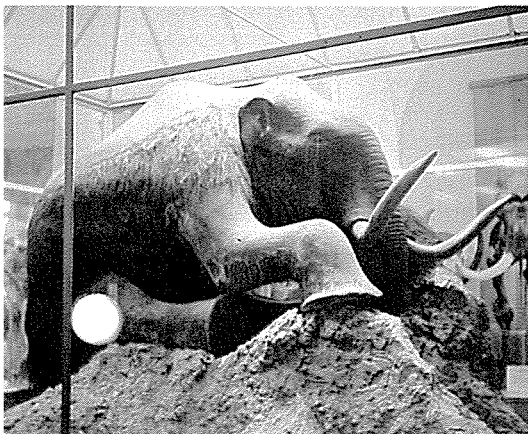
Surgeons replace a damaged heart with the Jarvik-7 – the most commonly used artificial heart. It costs about a million dollars. The 'Phoenix' heart (above), devised by an American dentist, is cheaper, but has not been officially approved.

and mice in the laboratory, taking away the nucleus of the mother's egg, and replacing it with the nucleus from a cell of donor tissue. Human experimentation has been carried out to a limited extent, but in many countries there are strict rules for research laboratories, which

RECYCLING ELEPHANTS

Mammoths found preserved in ice in Siberia are known to be at least 10,000 years old. Tribesmen there have even fed the flesh to their dogs as thaws and floods uncovered the huge, extinct creatures. It is possible that cell tissue, if recovered while still frozen, could be revived. If the nucleus was extracted from these mammoth cells and used to replace the nucleus of a cow elephant's fertilized egg, it may be possible to create a mammoth clone born of the elephant in the usual way. An extinct species, thus, could once again be re-established on Earth for the first time.

Novosti



Alexander Tsiaras/SPL

Lasers have revolutionized eye surgery, which requires extreme precision. The YAG laser mounted on an optical fibre is used in operations to replace lenses.

prevent experiments on human embryos created outside the body continuing after a certain number of days. The science fiction vision of a world full of identical 'worker clones', slaving away in factories, is never likely to arise.

Man's obsession with overcoming death has led some people to put their faith in cryobiology – the freezing of a body as soon as it has died – in the hope that at some future date it can be revived and made well again. A number of people have had their corpses frozen and sealed in deep-freeze caskets, waiting to be brought back to life at some future date.

Scientists have already succeeded in reviving bacteria found frozen for thousands of years in ancient ice-fields. Soviet scientists also claim to have discovered revivable cells in the bodies of woolly mammoths discovered preserved in ice and permafrost.



The surgeon's role

Replacement surgery is one of the major medical achievements of the second half of the twentieth century. Aging arthritic hips can be

replaced with new hips of steel and plastic. Blindness due to cataracts can now be reversed by replacing the clouded eye-lens with a new one made of acrylic.

Deteriorating arteries can be removed, and replaced with efficient new ones of polyurethane. Hearts and kidneys, too, can be replaced with artificial versions. In some cases, the body rejects the new item, or refuses to 'work' with it. New materials are being created as close as possible to the body's own materials. Some bone replacements incorporate synthetic versions of bone material, which eventually become completely accepted by the body with living tissue growing on to the artificial bone.

With transplant surgery, living tissue and human body parts are used to replace damaged ones. To overcome the body's natural reaction to reject the new part, transplant patients have to take anti-rejection drugs, and a major problem is that the drugs suppress a large part of the immune system, making them prone to infection.

Genetically-engineered monoclonal antibodies are living cell forms that are programmed to attack only certain cells in the body. Success with these will mean that the human body may be serviced as easily as the family car – with worn-out parts being taken out and new parts fitted from the shelf.

SPARE PARTS

Synthetic replacements are now used from head to toe to repair the human body. They include:

Skull plates, made from metal alloy, and used after brain surgery

Glass eyes, made of glass or plastic, to replace diseased or injured eyes

Bone implants, made of plastic or metal alloy, to replace missing bones or repair bone defects

Oesophageal tube, made of plastic, to bypass narrowing in the gullet

Heart valves, made of plastic or metal alloy, to replace diseased ones

Pacemaker, consisting of an electronic box powered by batteries, to regularize the heart after a heart attack

Breast implants, made of silicon gel, to increase size or replace the original after removal

Tendon implants, made of carbon fibre, to replace damaged tendons and ligaments

Knee joints, made of metal alloy to replace broken or arthritic knees

Finger joints, made of flexible rubber, to replace arthritic joints



CNR/SPL
Alexander Tsiras/SPL

The power of the surgeon to mend the body by replacing defective parts with artificial substitutes has been greatly enhanced by the use of lasers.

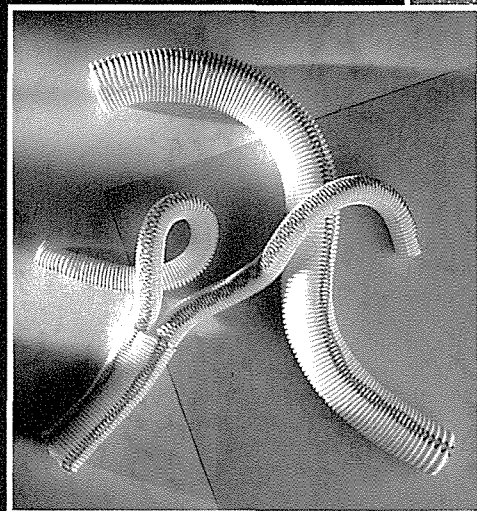
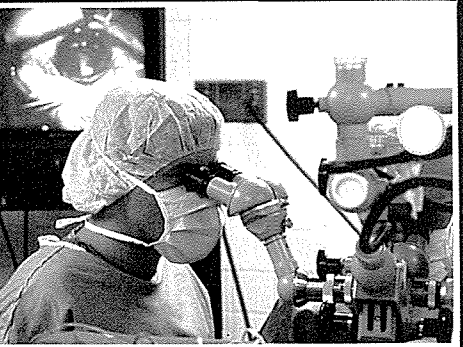
The hip-bone is connected to the thigh bone by a steel ball joint. The artificial part shows yellow against the green of the real bone in this false colour picture.



Reaching the parts other artificial hands have not reached, this French version grasps with precision and has great dexterity. It is activated by the forearm muscles without any other power source.

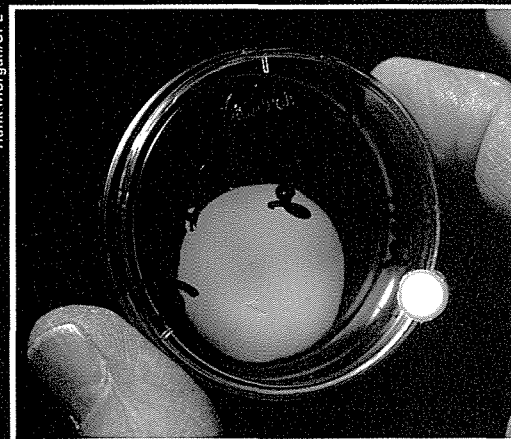


Cataract removal is one of the most commonly performed eye operations. It involves removing the clouded lens and, often, substituting a plastic implant. Here, the operation is filmed on video and simultaneously relayed to a lay audience to explain the procedure.



Knitted tubes replace diseased arteries. The smooth inside lets the blood through freely, while the hairy outside helps new tissue to grow over it (above).

Synthetic skin is grown in a culture dish by combining collagen and fibrous tissues. It is used for badly-burnt patients who have not enough of their own skin left for grafting.



J.M. Nossant/Gamma/Frank Spooner Pictures

Georgia Lowell/SPL

Hank Morgan/SPL

Design Council/Vasutek

SKY WARS

ADVANCES IN TECHNOLOGY are changing the face of aerial warfare. The original American F-15, for example, was designed as a fighter aircraft, but now, it has been turned into a bomber as well.

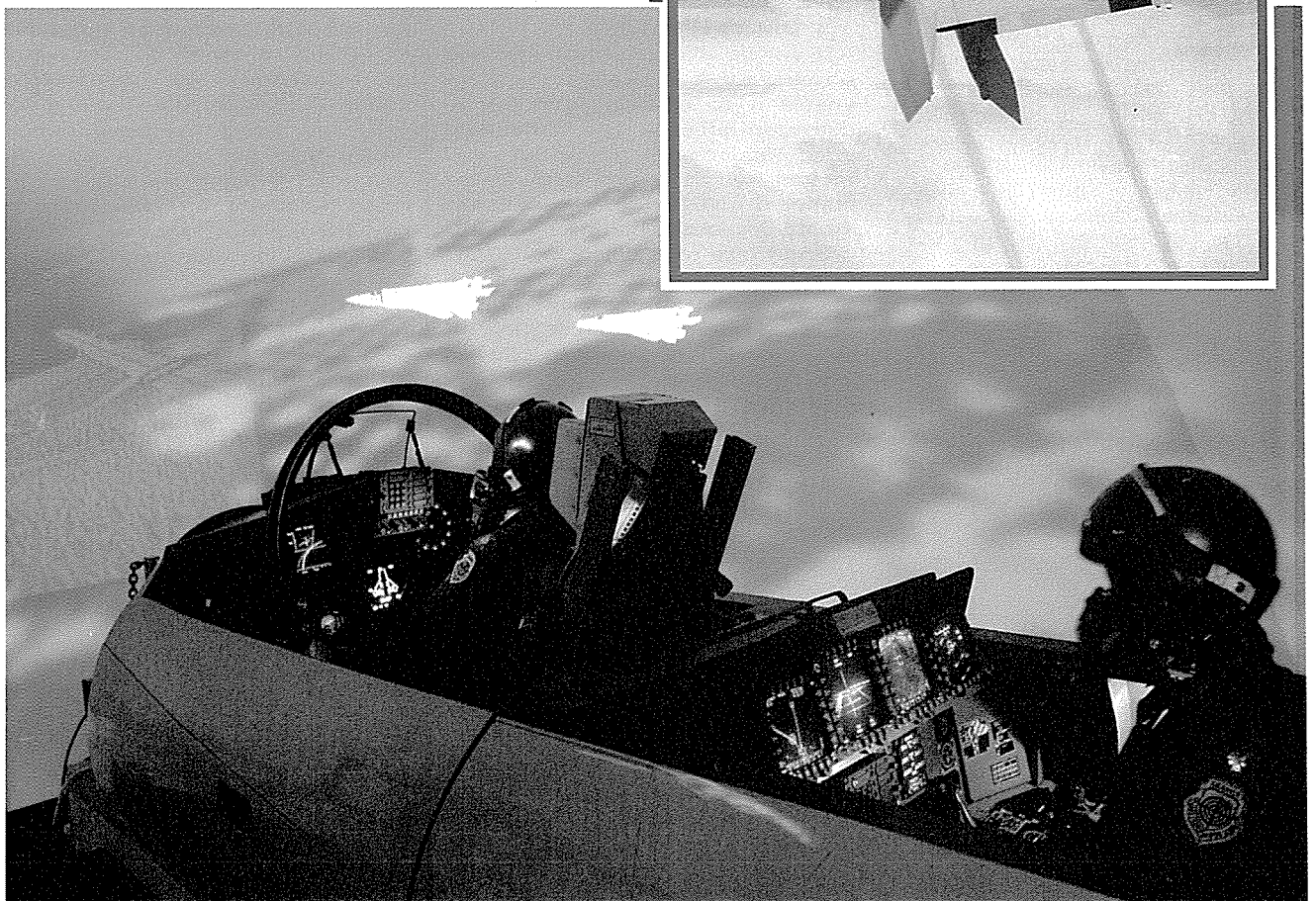
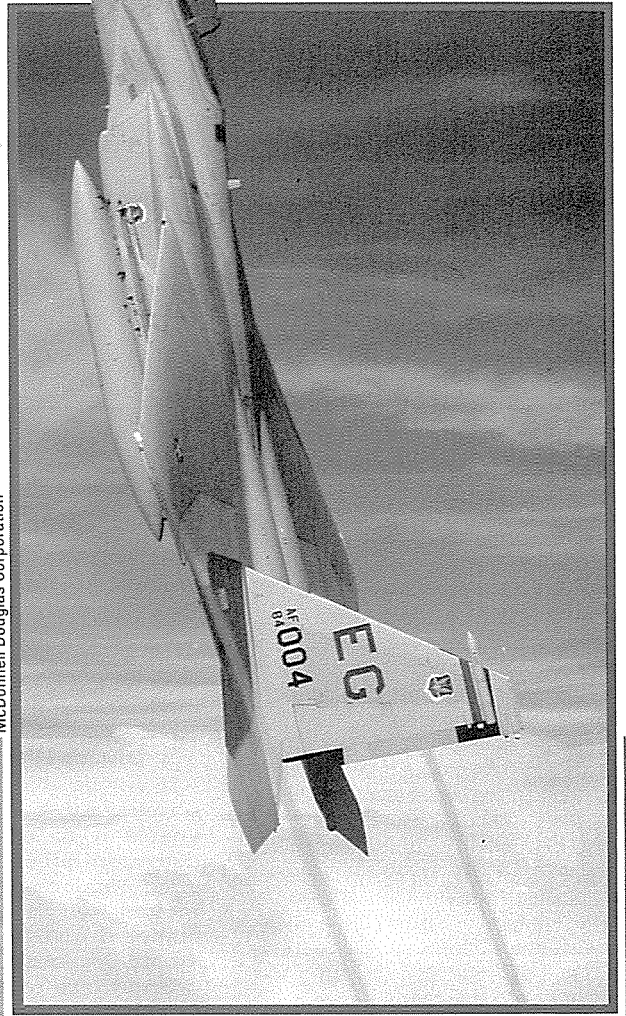
The F-15E Eagle long-range strike fighter carries extra fuel in tanks, which are shaped to fit the sides of the fuselage. Bombs are carried one behind another, so that the slipstream from the first bomb covers the second to reduce air resistance. Previous aircraft have given away their position by emitting radar signals that can be tracked by an enemy. Once close to its target, the F-15E can shut down its radar and navigate by an infra-red thermal image system.

The General Dynamics F-16XL design for the 1990s has an innovative 'cranked-arrow' wing, which acts as two wings in one. The inner section is similar to the conventional delta wing, found on a Vulcan bomber, but the outer, thin part

Fighter aircraft are frequently modified to improve their performance and to incorporate countermeasures against new weapons and detection systems. Improvements were made to the F-15's radar, computer and electronics systems.

Flight simulators are used to test the controls and displays of an aircraft. The pilot has information projected on to a glass screen in front of him, so he can still see out of the F-15E's cockpit while reading his instruments.

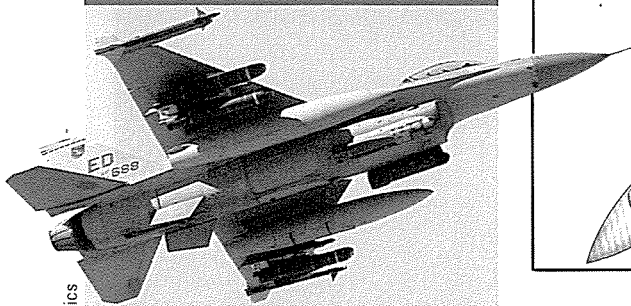
McDonnell Douglas Corporation



gives extra room for pitch and roll control surfaces. This makes the F-16XL highly manoeuvrable.

Cranked-arrow wings undergo complex stresses and rely on carbon fibre composite materials for their construction. The wing contains millions of tiny carbon fibres, held together with an epoxy resin. If the fibres are parallel, the wing will be stiffer in one direction than another. Unlike metal wings, carbon fibre wings can be designed to bend easily in some directions, but be very rigid in others. This technique is called 'aero-elastic tailoring'.

MISSILE FILE



General Dynamics

Missiles can be classified according to the role they perform. Air-to-surface missiles are carried by aircraft and used to attack targets on the ground. They can be guided by laser or radar. Surface-to-air missiles defend against airborne attack, as the British Aerospace Rapier demonstrated during the Falklands campaign in 1982. The F-16 (above) carries missiles for attacking both air and ground targets.

The American Aegis missile system can detect incoming aircraft and destroy them before visual contact is made. This was tragically demonstrated in July 1988, when the Aegis-fitted warship USS *Vincennes* accidentally shot down an Iran Air A300 Airbus.

The French-built Exocet is probably the best-known anti-ship missile. Other classes of missile include anti-submarine and anti-tank missiles.

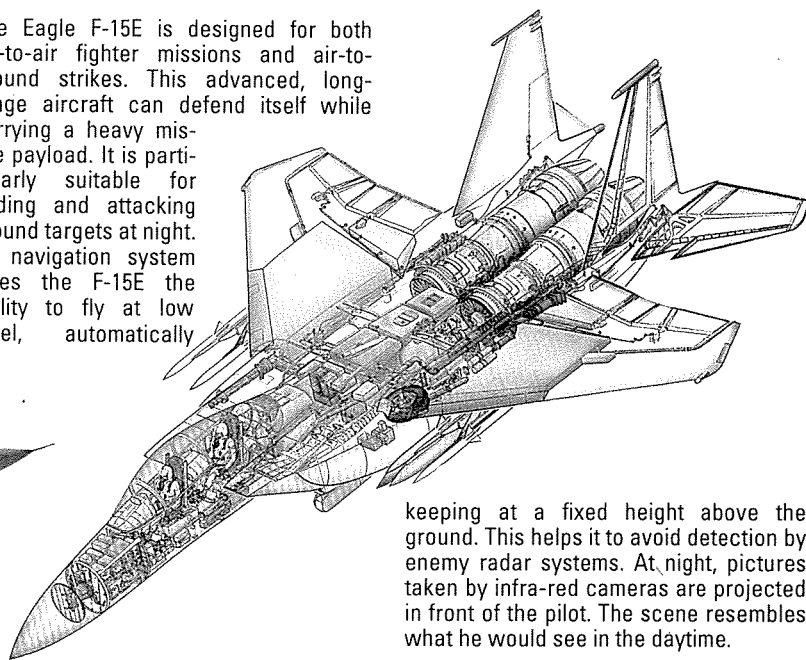
Strategic missiles include long-range as well as intermediate-range nuclear weapons. The US Ground Launched Cruise Missile (GLCM) has a nuclear warhead. GLCMs were deployed at RAF Greenham Common in December 1983, but have since been withdrawn. Russian strategic missiles comprise the SS series of weapon. The SS-20 missile entered service in 1977.



General Dynamics

DUAL-ROLE FIGHTER

The Eagle F-15E is designed for both air-to-air fighter missions and air-to-ground strikes. This advanced, long-range aircraft can defend itself while carrying a heavy missile payload. It is particularly suitable for finding and attacking ground targets at night. Its navigation system gives the F-15E the ability to fly at low level, automatically



keeping at a fixed height above the ground. This helps it to avoid detection by enemy radar systems. At night, pictures taken by infra-red cameras are projected in front of the pilot. The scene resembles what he would see in the daytime.

McDonnell Douglas Corporation

A United States Air Force proposal for the mid-1990s is the Advanced Tactical Fighter (ATF). ATF will fulfill a dual-mission fighter/attack role. The aircraft will be able to cruise and manoeuvre supersonically at an altitude of 20 km and beyond. ATF may be fitted with a forward-swept wing, which was tested on the Grumman X-29A research plane.



Short runways

ATF will be able to take off and land on very short runways, which will enable it to operate from bomb-damaged airfields. The target runway requirement is about 450 metres, which is one-sixth of the standard NATO (North Atlantic Treaty Organization) runway length.

Short take-off and landing (STOL) from a runway measuring just a few hundred metres long is already possible with some aircraft in current production. This capability is likely to become a standard requirement for the NATO warplanes of the early 21st century.

Another aircraft of the future is the advanced short take-off/vertical landing (ASTVOL) fighter. Various proposals have been put forward,

including one for a six-engined fighter. This will have four engines in swivelling pods on the wingtips, with another two fitted vertically in the fuselage. ASTVOL aircraft may replace the F-16 and Harrier II designs by the turn of the century.

The replacements for the successful Lockheed SR-71 Blackbird strategic reconnaissance aircraft will probably be flying by the year 2000. This may be capable of speeds around 6,500 km/h at an altitude of 35-40 km. Such an aircraft would be powered by supersonic-combustion scramjets. The engines will burn liquid hydrogen, which would also be used to cool the airframe. In-flight refuelling with liquid hydrogen may well prove to be impossible, however, which would limit the new aircraft's range.

Just amazing!

HAPPY LANDING

IN 1944, FLT-SGT ALKEMADE JUMPED 5,485 METRES FROM HIS BLAZING BOMBER WITHOUT A PARACHUTE. A FIR TREE AND SNOW DRIFT BROKE HIS FALL AND HE LIVED.



Paul Raymond

Manoeuvrability is an important feature of today's fighter aircraft. Because of its tight turning ability, the F-16's structure has been specially designed to withstand the extremely high stresses produced.



FLIGHT 2000

FUTURE JET ENGINES WILL produce a thrust of over ten times their own weight. They will therefore be more than three times as powerful as early jet engines.

Materials lighter than metal will have to be used in their manufacture to

help achieve such improvement in engine performance. Some of the most promising new engine materials are ceramics, such as silicon nitride and silicon carbide. They are stronger than metals, but only half as dense as the alloys they are destined to replace.

Engine manufacturers Pratt and Whitney are working on a combined carbon fibre and ceramic material called 'Compglas', which has already been successfully tested in aero engines. The engines of the future may even produce thrust to weight ratios of 15:1 – nearly five times as good as their early predecessors. New materials will also have an important role to play in airframes as well as engines.

Vehicles that fly at high speed can become very hot owing to friction with the air. The new materials, therefore, need to be both light and able to withstand high temperatures. One possibility being studied is a carbon-ceramic matrix. This would comprise carbon fibres embedded in silicon carbide.



Stealth technology

Another area where new technology is coming to the fore is the so-called Stealth aircraft. The best way to avoid a fighter aircraft being shot down is to make it invisible. This was done in the early days of

aviation by painting planes with camouflage patterns, but fancy paintwork is not much use to a modern fighter pilot.

Nowadays, pilots may find themselves in combat with other aircraft they cannot even see. It is possible to be shot down without ever seeing the aircraft that fired. Modern warfare relies on radar to detect potential enemy targets. To make an aircraft invisible, it has to be made invisible to radar. That is where Stealth technology comes in.

One way to modify an aircraft's 'radar signature' is to change its shape. Thin, flat aircraft reflect much less radar energy than thicker, conventional designs. The ideal Stealth aircraft would resemble a



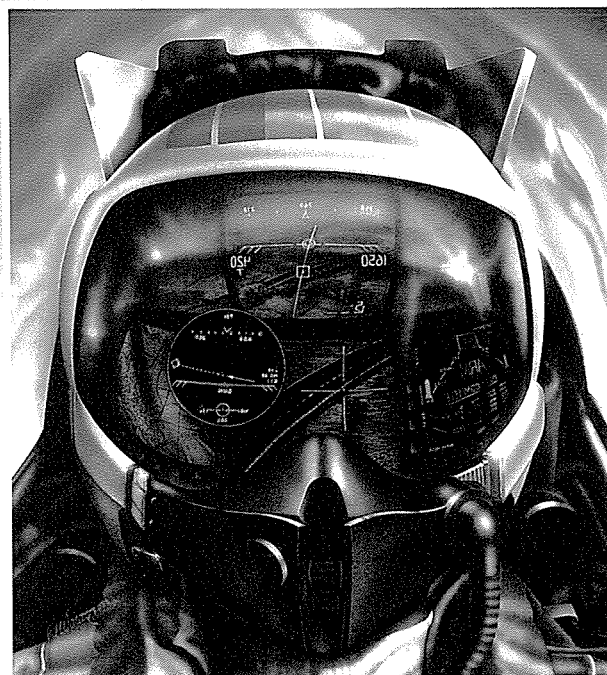
INVISIBLE PLANES



VOICE CONTROL



EJECTOR SEATS



Kaiser

The future of flight – the film Firefox foresaw developments that have become a reality. The new Agile Eye helmet uses a cathode ray tube to relay information to the pilot wherever he moves his head.



flying pancake and present a very small cross-sectional area to a radar beam. Other steps can be taken to reduce the amount of radar energy that is reflected. For example, anti-radar paints, which are poor reflectors of radar signals, can be used to cover the airframe.



Frank Spooner Pictures

The Lockheed ER-2 was purpose-built for NASA (the National Aeronautics and Space Administration). It is the prototype of the TR-1 spyplane.

There are further steps that can be taken to render an aircraft undetectable. Emissions of sound, smoke trails, infra-red (heat) radiation and radio waves have to be minimized as well.

Race against time

Forty years ago, an enemy plane that was 30 km away would take a couple of minutes to come into

view. In that time a pilot would be able to check his position, his weapons systems and get ready for the ensuing battle. Nowadays an enemy plane travels at such speed that it would cover the 30 km in under 30 seconds, allowing the pilot very little time to prepare for combat.

Researchers have been exploring ways of taking some of the workload away from the pilot, and making the controls quicker and easier to use. Computers will navigate the plane, control the engines, and remind the pilot of any necessary course of action.

The cockpit

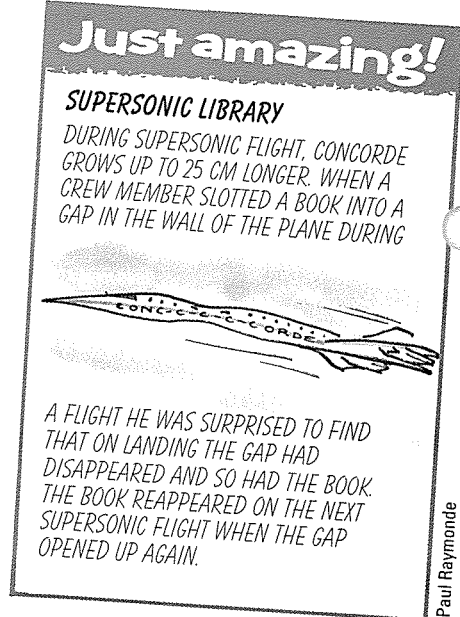
Most up-to-date fighter aircraft are already fitted with Head Up Displays (HUD), which allow the pilot to check the main instruments and the

AROUND THE WORLD IN NINE DAYS

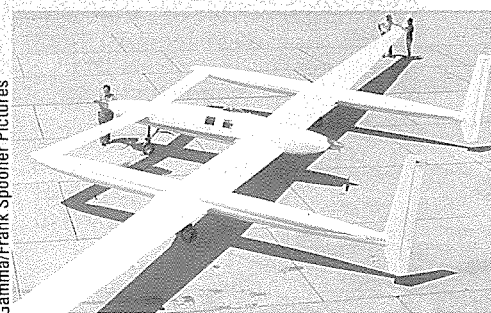
Dick Rutan and Jeana Yeager flew non-stop around the world without refuelling in their specially constructed *Voyager* aircraft. They left Edwards Air Force Base in California, USA, on 14 December 1986, returning on 23 December. The total duration of the flight was 9 days, 3 minutes and 44 seconds. *Voyager* had flown for 40,253 km at an average speed of 186 km/h.

The pilot flew the plane from a cockpit measuring 1.7×0.54 metres and the other crew member rested in a space measuring 2.3×0.6 metres.

Voyager was designed by Dick Rutan's brother, Burt, who first sketched his ideas on the back of a paper napkin in a restaurant. The aircraft was constructed using many novel lightweight



Paul Raymonde



Gamma/Frank Spooner Pictures

materials, including graphite and paper.

It has a wing span of 33.77 metres and can carry 5,636 litres of fuel weighing 4,052 kg. The aircraft took more than two years and 22,000 man-hours to build.

ESCAPING DEATH

With the introduction of jet-powered aircraft, the possibility of a successful 'over the sides' bale out was virtually eliminated. Thus the forced ejection of a pilot became a necessity.

The most effective ejection seat currently in use is the Advanced Concept Ejection Seat II (ACES). In the last ten years, ACES II has saved the lives of more than ten pilots.

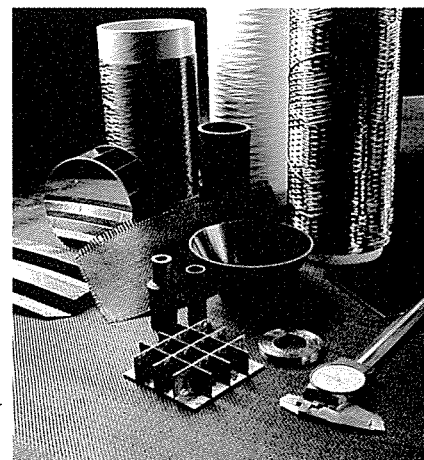
To trigger the ejection sequence, the pilot must pull his face cover over his head. At this point thin strands of explosive shatter the canopy. This is followed by a series of small charges, which push the seat clear of the cockpit. Once the seat is free, a booster rocket propels the seat for a few hundred metres from the aircraft. At this point, the seat automatically unstraps the pilot, leaving him free to parachute safely to the ground.

Today's seats are a long way from the days when a pilot had to unstrap himself from the seat and then release his parachute. In those days, many a pilot fell to the ground and died, still strapped to his seat.



radar display without looking down into the cockpit. But the image on a HUD appears to be quite close to the pilot, so he still has to re-focus his eyes from instruments to target and back again.

The aircraft of the future will



McDonnell Douglas Corporation

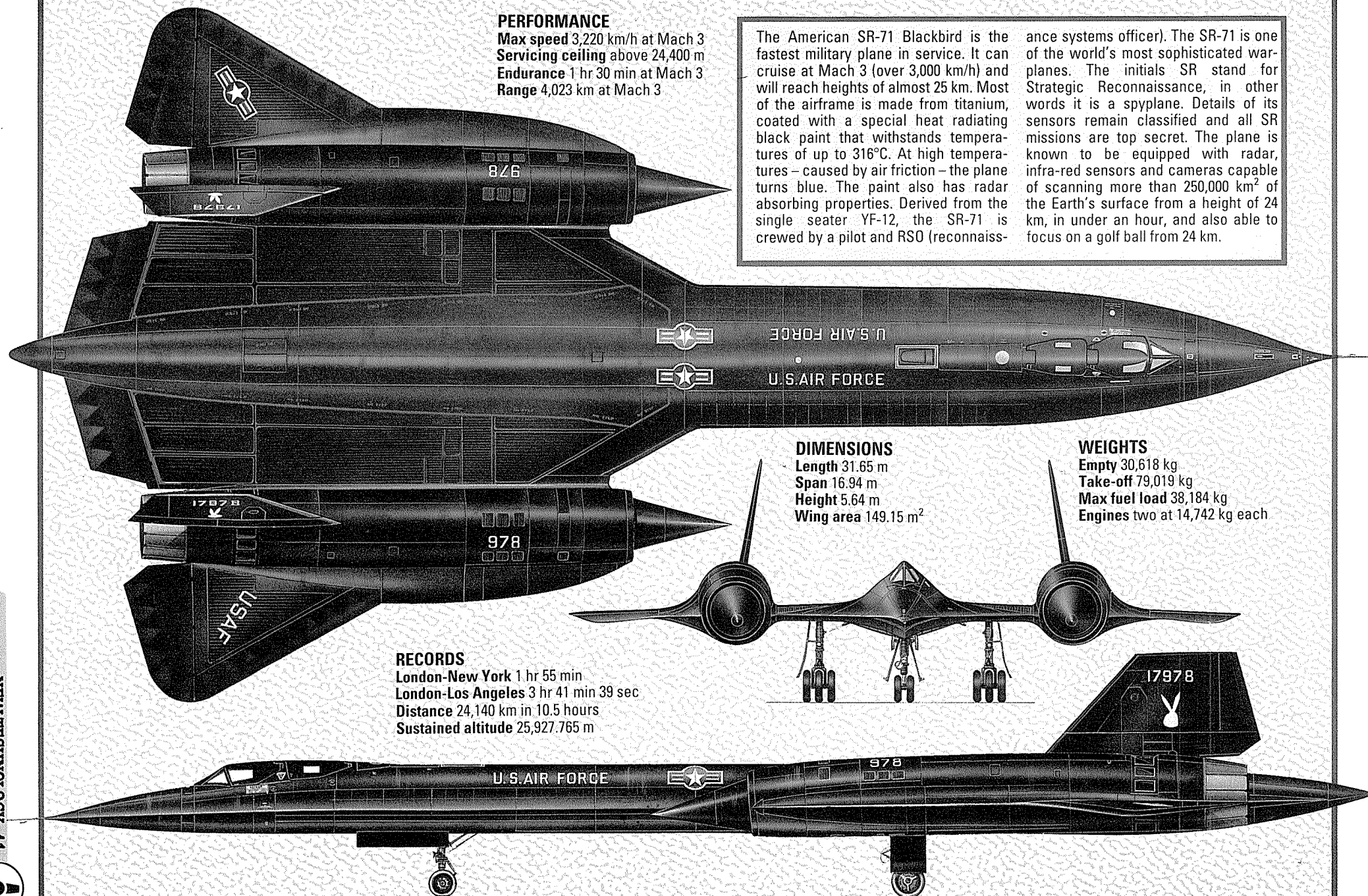
United Technologies

Gas turbine engine components made from compglas have proved to be exceptionally strong and stable at high temperatures.

PERFORMANCE

Max speed 3,220 km/h at Mach 3
Servicing ceiling above 24,400 m
Endurance 1 hr 30 min at Mach 3
Range 4,023 km at Mach 3

The American SR-71 Blackbird is the fastest military plane in service. It can cruise at Mach 3 (over 3,000 km/h) and will reach heights of almost 25 km. Most of the airframe is made from titanium, coated with a special heat radiating black paint that withstands temperatures of up to 316°C. At high temperatures – caused by air friction – the plane turns blue. The paint also has radar absorbing properties. Derived from the single seater YF-12, the SR-71 is crewed by a pilot and RSO (reconnaissance systems officer). The SR-71 is one of the world's most sophisticated war-planes. The initials SR stand for Strategic Reconnaissance, in other words it is a spyplane. Details of its sensors remain classified and all SR missions are top secret. The plane is known to be equipped with radar, infra-red sensors and cameras capable of scanning more than 250,000 km² of the Earth's surface from a height of 24 km, in under an hour, and also able to focus on a golf ball from 24 km.



DIMENSIONS

Length 31.65 m
Span 16.94 m
Height 5.64 m
Wing area 149.15 m²

WEIGHTS

Empty 30,618 kg
Take-off 79,019 kg
Max fuel load 38,184 kg
Engines two at 14,742 kg each

RECORDS

London-New York 1 hr 55 min
London-Los Angeles 3 hr 41 min 39 sec
Distance 24,140 km in 10.5 hours
Sustained altitude 25,927.765 m



HEAVY-DUTY FLIER



Aviation Picture Library

The world's heaviest and most powerful bomber is the eight-jet, swept-wing Boeing B52 Stratofortress. It made the first ever non-stop flight round the world by a turbojet-powered aircraft in 1957. Twenty-three years later, the Stratofortress broke the record for the fastest non-stop round-the-world flight which took 42 hr 30 min. Refuelling was carried out in the air. The Boeing B52 Stratofortress can carry twelve thermo-

nuclear short-range attack missiles (SRAM's) or twenty-four 340 kg bombs under its wings, and eight more SRAMs or eighty-four 226 kg bombs in the fuselage. It also carries four 12.7 mm guns in the tail turret.

- **Length** 48.02 m
- **Wing span** 56.38 m
- **Max speed** 957 km/h
- **Max take off weight** 221.35 tonnes
- **Max bomb load** 31,751 kg

overcome this problem by projecting computer-generated instrument readings into the pilot's forward field of view. The computer will be used to generate data, which is fed to miniature television screens mounted on the pilot's helmet. The same type of optics used in binoculars would then project the image into the pilot's field of view. Data would thus appear superimposed on the landscape before his eyes.

The system could also be used for night flying. An image intensifier night-sight could produce an image of the landscape and feed it to the

pilot via his helmet projector system. The view could even be made three-dimensional by sending a slightly different image to each eye — just as in ordinary vision.

As well as 3-D vision, 3-D sound could be provided. For example, a radio message from another aircraft flying to the left of the plane would be arranged to sound louder in the pilot's left ear than in his right. This would make the sound appear to come from the direction of the aircraft that sent the message.

The pilot of the future may be able to control his aircraft by using his voice instead of his hands. Voice

control would be a great time-saver as the pilot would no longer have to go through the process of looking for, and then pressing, a switch or button. He would be able to concentrate fully on the screen in front of him. Engineers in France have been working on such a system since 1982. Similar work is being undertaken in the UK and USA.

One of the main problems that has to be overcome is cockpit noise. The pilot's voice will be unable to control the aircraft if other sounds drown it out. Tests have shown that the computer can recognize as many as 96 per cent to 99 per cent of a pilot's commands, but even 99 per cent is not good enough. It is only when the system can recognize 99.99 per cent of the spoken commands that the equipment will be put into operation.

Visual control

Aircraft designers are also looking at the possibility of switches that are activated just by looking at them, and systems that can read the pilot's brain waves.

The present-day pilot needs to see where he is going in order to fly safely. This is easy enough in daytime, but night flying is a different matter. Image intensifiers and night sights are already being used to enable pilots to see in the dark, but the pilot of the future may not need to see where he is going at all.

The satellite-based global positioning system, or GPS, will enable the pilot to know his position in three dimensions to within 16 metres. GPS will work out its position by means of signals from four or more orbiting Navstar satellites.

INTO THE FUTURE

WIRED FOR THOUGHT

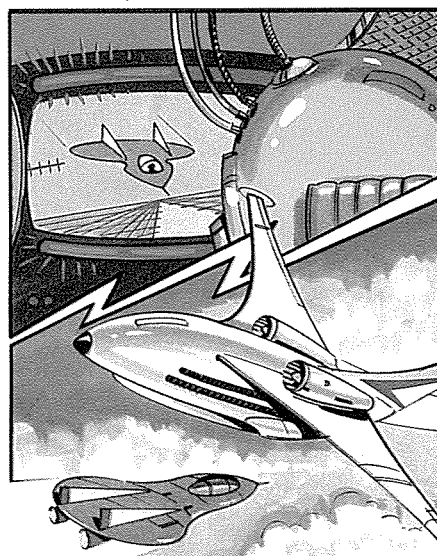


Joe Lawrence

▲ Tomorrow's planes will have a computer screen that simulates the terrain below. The image will be crystal clear — whether it is day or night.



▲ The pilot's head will be wired to computers, which can detect his brain waves. By thinking a command the pilot will control the plane.

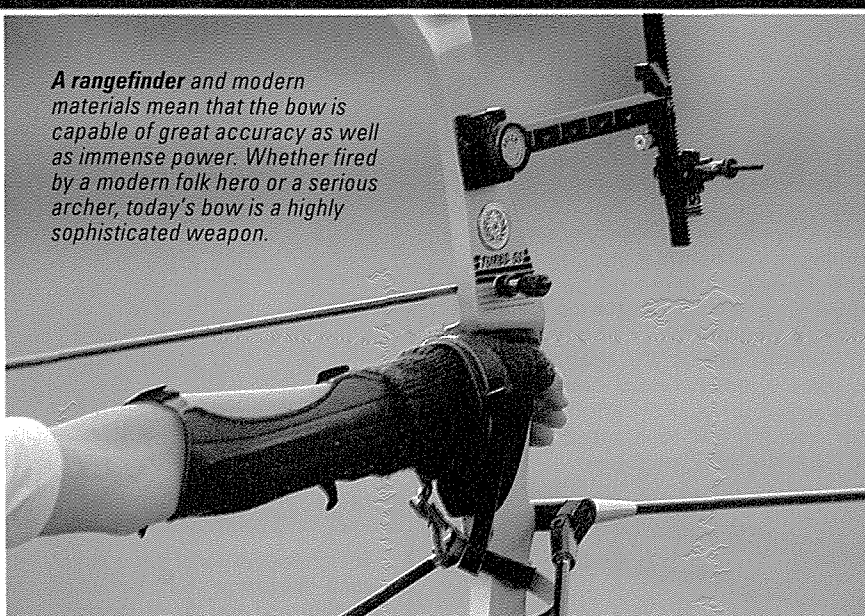


▲ If the pilot gets tired or makes a wrong decision, the computers will modify his orders. This could involve taking evasive action to avoid a collision.



- ☐ POWER WITHOUT EFFORT
- ☐ RAZOR-SHARP BROADHEADS
- ☐ THE DEADLY BOLT

BOW HUNTER



A rangefinder and modern materials mean that the bow is capable of great accuracy as well as immense power. Whether fired by a modern folk hero or a serious archer, today's bow is a highly sophisticated weapon.

Pascal Rondeau/All Sport

TRAVELLING AT OVER 60 metres per second, a well-aimed arrow from a modern bow can bring sudden death to anything from a squirrel to a grizzly bear.

Armed with new versions of the traditional longbow and crossbow, or with the revolutionary compound bow, American hunters are leaving their rifles at home and going to the woods bow-hunting.

Today, the number of target archers in the USA is only a few thousand, but there are over two million bowhunters and more people are taking up the sport each year. One of the main reasons for the growing popularity of bowhunting is the compound bow, which first came on the market in the early 1960s. It is easier to use than a conventional longbow, and its high-tech look appeals to Americans.

Compound bows

The most obvious feature of a compound bow is the ingenious pulley-like systems of off-centre wheels and cables, which replaces the single string of an ordinary bow.

This cable system gives the arrow more rapid acceleration, and also makes it easier for the archer to hold the bow fully drawn while he takes aim. If an ordinary longbow needs a pull of, say, 20 kg to draw it, then it needs the same amount of force to hold it drawn. A compound bow of the same power still needs a pull of 20 kg to draw it, but only 10 kg — half the power — to hold it drawn. Since it can take a pull of 45 kg or more to draw a big-game bow, this is an obvious advantage.

The compound bow has a rigid wood or metal handle section in the middle, often shaped to give an almost pistol-like grip. On a hunting bow, this handle section may carry

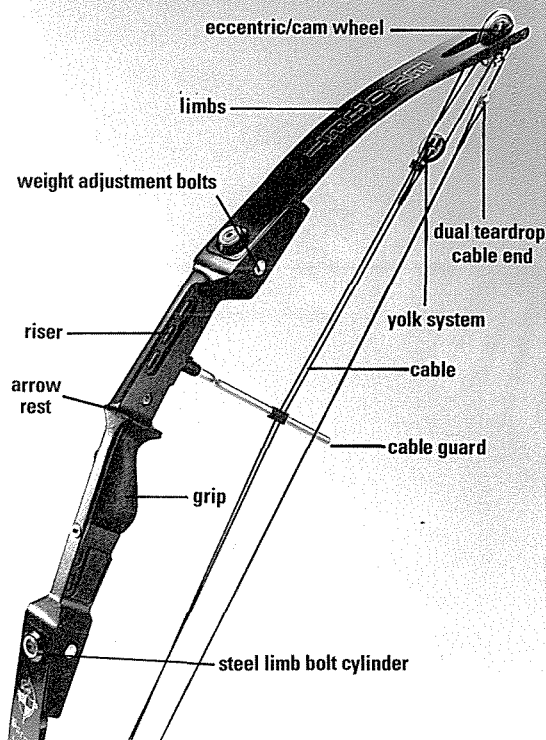
sighting and rangefinder scales and a rigid quiver to hold spare arrows.

The upper and lower limbs of a compound bow were originally made of wood or wood laminates, and although these are still used, limbs today are more likely to be made of plastic, magnesium, aluminium, glassfibre or carbonfibre. Each limb is fixed to the handle by a large bolt, and by tightening or loosening these bolts, the draw force of the bow can be varied.

The modern arrow

The arrows used for hunting are usually about 72 cm long, made of aluminium tubing or cedar wood. They have a razor-sharp triangular





A system of wheels or cams, incorporated into the limbs of the compound bow, allows it to deliver power with the greatest possible economy of effort – the 'hold weight' of the bow is only half the 'draw weight'.

Arrow technology has advanced over the years to keep pace with bow technology. The modern arrow, unlike its predecessor, which was usually made of wood, is now made of aluminium with plastic flights instead of feathers. A well-aimed arrow could easily kill a fox, but hunting for game with a bow and arrow is illegal in the UK.

broadhead at one end and flights of feather or plastic at the other.

The arrowhead is made as sharp as possible – and a good hunter will keep it that way – to ensure that it will kill the game and not just wound it, which would cause unnecessary suffering. A blunt arrow would also be a danger to the hunter, who could find himself confronted by a wounded and angry grizzly bear or mountain lion, with no time to reload and shoot again.

Despite arrow speeds of up to 60 metres per second, hunting with a compound bow can be far more difficult than with a rifle, because of the bow's shorter range. If he is going to have any chance of a kill, the bowhunter has to be able to get to within about 35 metres of his quarry without being detected. But if a bowhunter wants longer range, he can switch to a more powerful weapon – the crossbow.



Pascal Rondeau/All Sport

In the UK, crossbow ownership is regulated. No-one under the age of 17 years is allowed to purchase one of these bows, although individuals under 17 years can use them provided they are supervised by an adult of 21 years or over.

Crossbows

Shooting with a modern crossbow is more like using a rifle than a bow. The limbs of the bow, called 'prods' on a crossbow, are mounted at the end of a 'barrel', similar to a rifle stock, with a trigger mechanism. Many hunters fit their bows with telescopic sights.

The barrel is usually made of wood or light alloy, and the prods of laminated wood, glassfibre or carbonfibre. To cock the bow, the string is pulled back by hand, or by a lever or winch mechanism, and hooked on to the top of the trigger mechanism.

For hunting, the bolt (as the crossbow arrow is called) is between 35 and 45 cm long – much shorter than a hunting arrow, but carrying the same lethal broadhead and flights of feather or plastic. The effective hunting range is up to 55 metres, and bolt velocities can be over 75 metres per second.

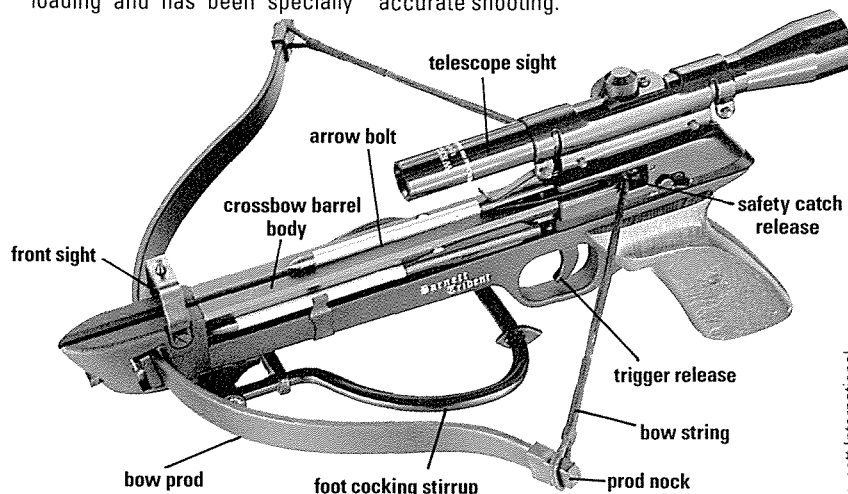
Like the compound bow, the crossbow is used for hunting anything from small game such as rabbits to deer and big game, including elk and bear. There is no recoil, so the crossbow is more comfortable to shoot than a large-bore rifle. But contrary to popular belief it is not all that silent.

For small game at close range – up to 15 metres – there are a number of crossbow pistols on the market. They shoot miniature bolts, and some even have a rotating barrel system holding five bolts. After each shot, the bow is recocked and the barrel turned to bring the next bolt into position.

A LETHAL WEAPON

The crossbow pistol has a three-shot magazine for simplified loading and has been specially

designed to withstand reverse recoil, which allows for more accurate shooting.



Barnett International



Paul Raymond



DECOYS

ARMOUR PIERCERS

EVADING RADAR

The Rockwell B-1B bomber is hard to detect as it provides a poor target for radar.

COUNTER ATTACK

SOME OF THE LATEST aircraft can not only escape from the missiles fired at them, they are designed in such a way that they are less visible to radar, so are unlikely even to be spotted by the enemy.

Whenever a new or improved weapon enters service, it is usually only a matter of time before someone comes up with a defence against it. When anti-tank missiles were first introduced, they could almost be guaranteed to make a kill, but soon new armour was developed to resist them.

Among the toughest tanks in the world, equipped with special armour, is the Russian T-72 main battle tank (MBT). This tank, together with its specialist versions the T-74 and T-80, is in service with several ex-Communist armies. It is designed to spearhead a major conventional attack. The armour is specially made to withstand almost any shell or missile.

Tank armaments

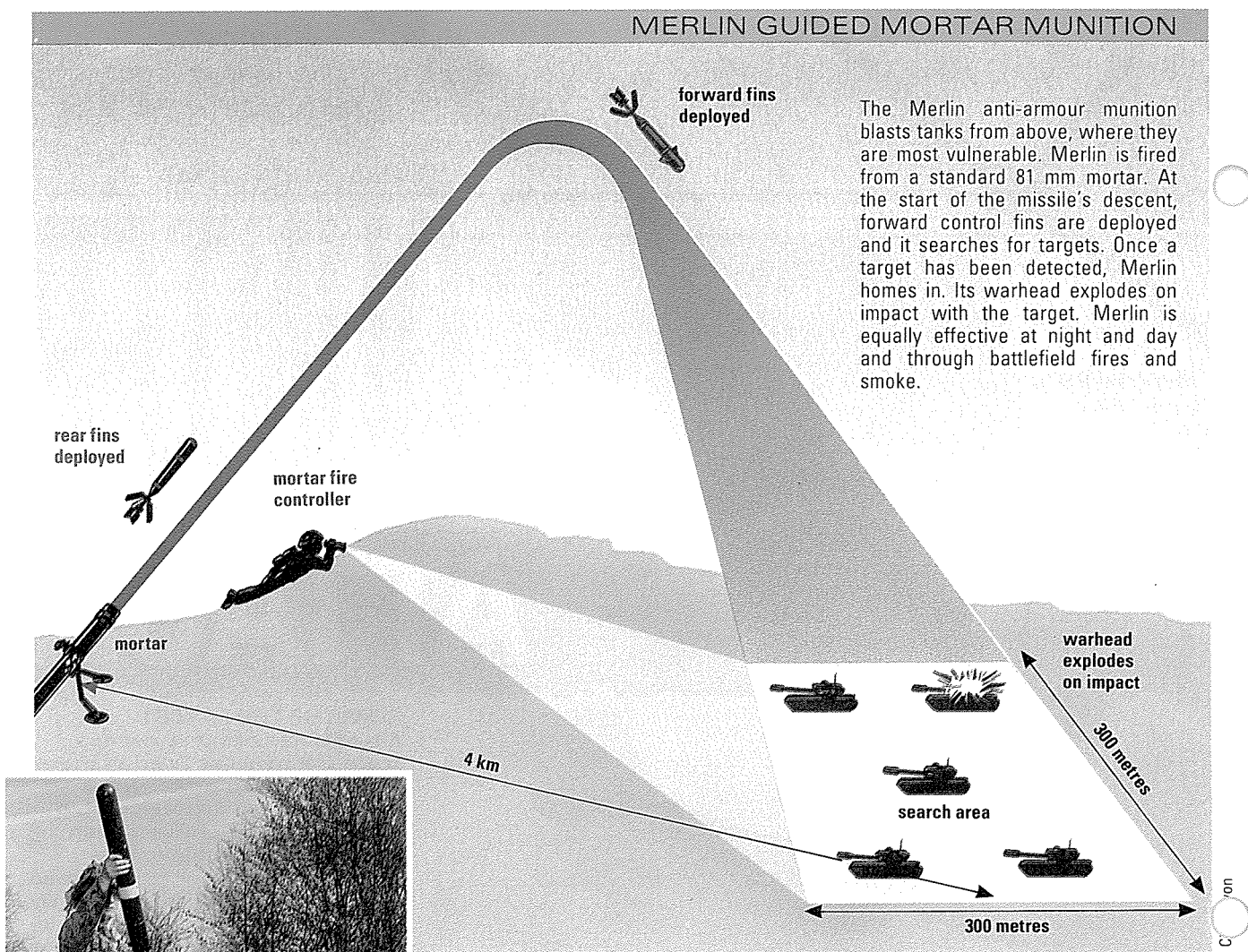
The main armament of the T-72 is a 125 mm smooth-bore gun, with an automatic loading system, which gives it a rate of fire of eight shots a minute. To make these shots lethally accurate, the T-72 has a laser rangefinder and a computer-controlled gun stabilizer. Once the gun has been aimed, sensors monitor the motion of the tank, and the stabilizer continually alters the angle of the gun, keeping it trained on the target as the tank moves.

For use against tanks and other armoured vehicles, the T-72 carries two main types of armour-piercing shell. The first is called an armour-piercing, discarding sabot (APDS)

A TV-guided AGM-65 Maverick air-to-surface missile is launched from a US Air Force F-16B fighter.



MERLIN GUIDED MORTAR MUNITION



shell. It has a small diameter, solid tungsten carbide shell enclosed in a 125 mm light alloy sleeve, or sabot.

When the shell leaves the barrel at a speed of 1,615 metres per second, the light-alloy sabot breaks up and falls away, and the shell flies on to smash through the armour of its target. It can penetrate ordinary cast steel armour up to 300 mm thick at a range of 1,000 metres, and its maximum range is 2,100 metres.

The second type of shell is a high-explosive anti-tank (HEAT) round, which leaves the gun at 900 metres per second. When the shell hits its target, a detonator ignites its explosive warhead. The nose of the shell is designed to focus the blast

of the explosion into a narrow jet. This punches through the armour, erupting into the tank as a stream of hot gases and molten metal.

Both types of armour-piercing shell used by the T-72 are stabilized by fins to make them more accurate. So is the high-explosive fragmentation shell it carries for attacking troops or buildings. Its maximum range is 9,400 metres.

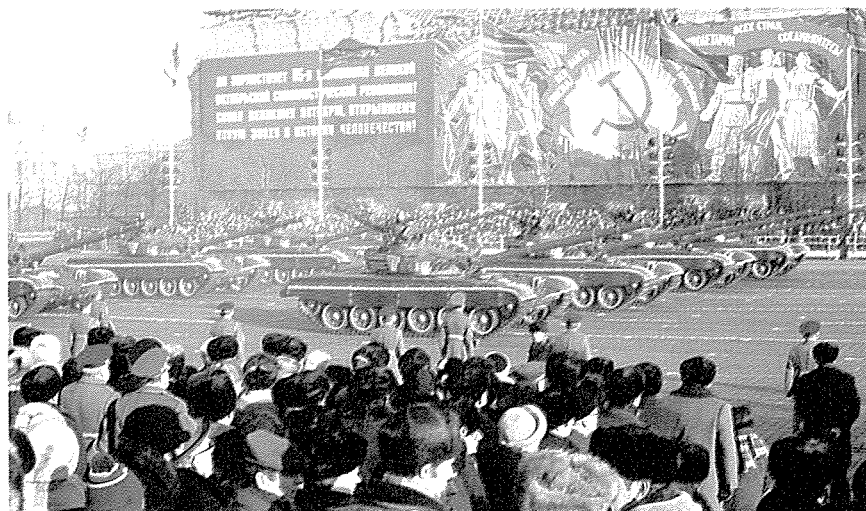
As well as the massive 125 mm main gun, the T-72 carries two machine guns: a 7.62 mm gun at the front of the turret, and a 12.7

mm gun on top. Both can be used against ground targets, but the T-72 can also use its 12.7 mm gun to defend itself against attack from the air — one of the biggest threats to a modern tank.

Air attack

The turret of a tank is its most vulnerable point. It has to be relatively light to be swivelled quickly, so the armour cannot be as heavy as that of the tank's hull. And because it has various hatches, gun ports, and gunsight and periscope

The T-72 tank, seen here at a Soviet parade, is now used by most ex-Soviet states.



Ilkka Ranta/Lehtikuori



McDonnell Douglas Corporation



The AH-64 Apache attack helicopter is heavily armed and carries Sidewinder and Stinger air-to-air missiles as well as eight Hellfire anti-tank missiles on its wing pylons.

mountings in it, parts of it cannot be fully armoured at all.

An attack from the air is one of the surest ways to destroy a tank, blasting its turret apart with a missile, a bomb or a hail of armour-piercing bullets. A ground-attack fighter firing Maverick missiles, or a McDonnell Douglas AH-64 helicopter with its Hellfire missiles, can take out any modern MBT, including the T-72.

Whenever a jet or helicopter gets close enough to enemy tanks to attack them, it might also find itself within range of the enemy's anti-

aircraft guns and missiles. Anti-aircraft missiles are guided to their targets by radar beams, heat-seeking sensors, television cameras or laser beams, so modern strike aircraft need ways of confusing or jamming the missile guidance systems to avoid disaster.

Obscured by clouds

The simplest forms of defence against anti-aircraft missiles — whether surface-to-air or air-to-air — are decoys dropped from the aircraft to lure the missiles away from it.

Radar-guided missiles can be put off the scent by 'chaff' — a cloud of short, metal-coated plastic fibres, each about 0.1 mm in diameter. When the aircraft's radar warning receiver detects a missile guidance

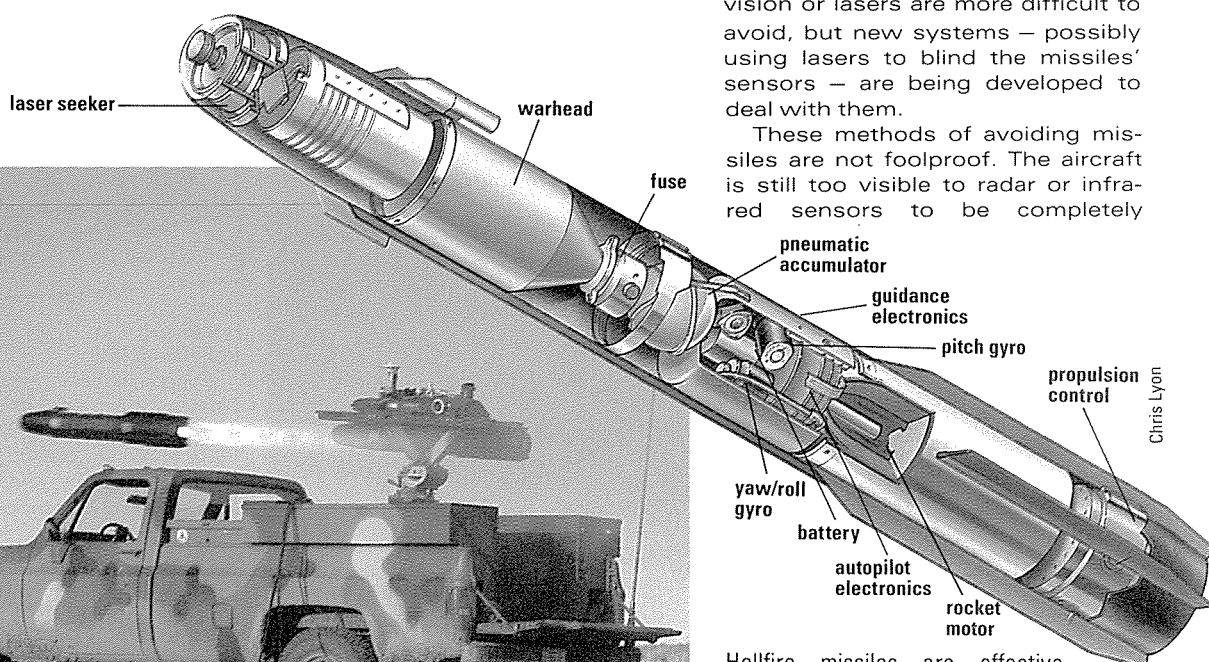
radar locked on to it, the plane releases chaff.

The chaff forms a slowly-drifting cloud, and the metallic coating of the fibres reflects the radar signals, just as the aircraft does. The missile homes in on the larger chaff cloud, while the plane flies on unharmed.

Heat-seeking missiles home in on the infra-red (heat) radiation given off by the aircraft's hot engine exhausts. To fool these missiles, the plane fires fiercely-burning flares. The missile follows these instead of the aircraft.

A more complicated, but highly effective, defence against missiles is to use electronic systems, called electronic countermeasures (ECM), to create false radar or infra-red signals that send the missiles off course. Missiles guided by television or lasers are more difficult to avoid, but new systems — possibly using lasers to blind the missiles' sensors — are being developed to deal with them.

These methods of avoiding missiles are not foolproof. The aircraft is still too visible to radar or infra-red sensors to be completely



Chris Lyon

HELLFIRE



Hellfire missiles are effective against tanks, bunkers, ships and helicopters. These missiles can be launched from land, sea or air. The solid fuel rocket motor enables Hellfire to move faster than sound.





TRH/Al

Israeli Kfir C2 fighters, armed with Shafrir air-to-air missiles, stand ready on the runway.

immune from a successful attack.

Because of this, the Americans (and perhaps the Russians too) are spending a lot of time and money on developing planes that are invisible to radar and other detection systems — the so-called 'Stealth' aircraft.

Stealth technology

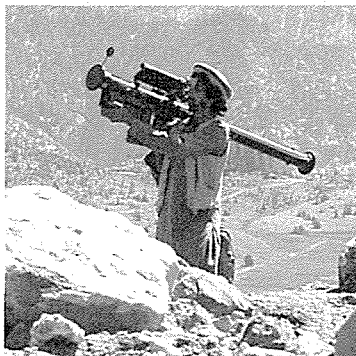
Radar signals are reflected by metal surfaces, especially if they are flat or sharply angled. To reduce the amount of radar signals they reflect, some Stealth planes have smooth curved surfaces that let the radar beams bend around them, and as many parts of them as possible are built of non-metallic materials, such as carbon fibre.

Those parts of the plane that must be made of metal, such as the engines and the weapons, are concealed within it and surrounded by surface materials that absorb radar waves.

Besides confusing radar systems, Stealth planes can avoid being detected from the ground by using their infra-red emissions. The engine outlets are on top — instead of below or at the rear of the plane —

STINGER MISSILE

The Stinger anti-aircraft missile is fired from the shoulder and uses a heat-seeking guidance system to home in on the target. Each weapon costs about \$50,000 and weighs nearly 16 kg. After an eight-week training course, troops using the Stinger missile score a 70 to 80 per cent hit rate.



Gamma/Frank Spooner Pictures

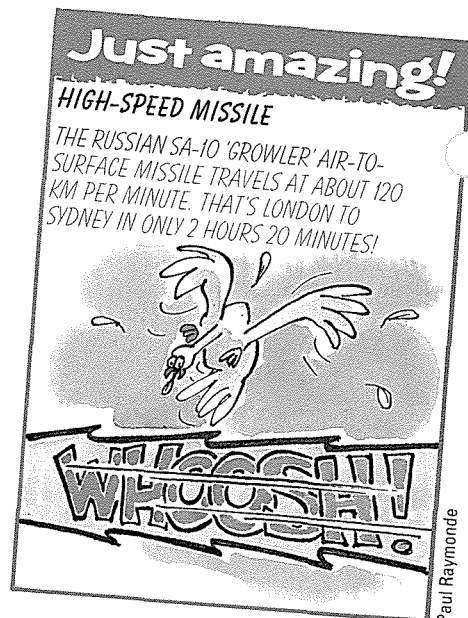
and the exhaust gases are cooled by mixing them with cold air as they leave the engine.

Despite all this, there is still a chance of the plane being detected by very sensitive radar, or from its own radar signals. So Stealth planes are equipped with highly

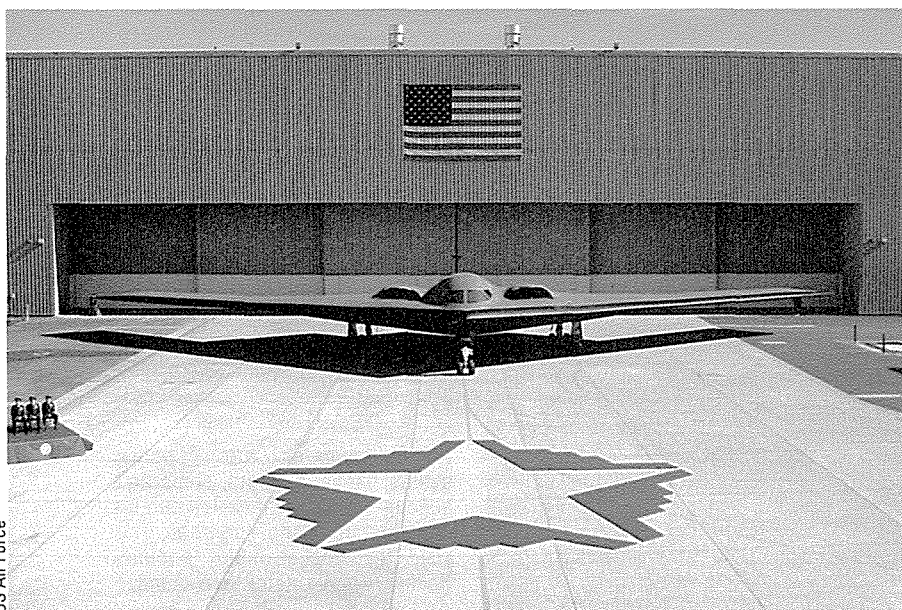
complex ECM systems. These mislead enemy radars about the size, speed, position and direction of the planes, making it difficult for the enemy to know whether, or how, to attack them.

Secrets revealed

Some aspects of Stealth technology are used on the Rockwell B-1B bomber. Its smooth shape, especially when seen from the front, and the design of its engine air intakes give it a radar 'signature' — the size it appears to be when seen on radar — of between one-tenth and one-



Paul Raymond



US Air Force

hundredth of that of its predecessor, the B-52.

Two much more advanced Stealth planes were originally so secret that the US Government denied their existence. These are the F-117A Stealth jet fighter and the Stealth B-2 bomber. The F-117A has sharp points and edges that give a highly confusing image on enemy radar screens. This design contrasts with the rounded edges of the B-2, which are designed to minimize radar reflections.

The B-2 Stealth bomber was designed by Northrop Corporation in conjunction with Boeing and Vought. It is powered by four concealed F101 engines.



THE NUCLEAR AGE

- FISSION AND FUSION
- THE NEUTRON BOMB
- DEADLY WARHEADS

NUCLEAR WEAPONS ARE THE most destructive ever invented. The massive explosive power of just one intercontinental missile, with multiple warheads, could destroy a whole city.

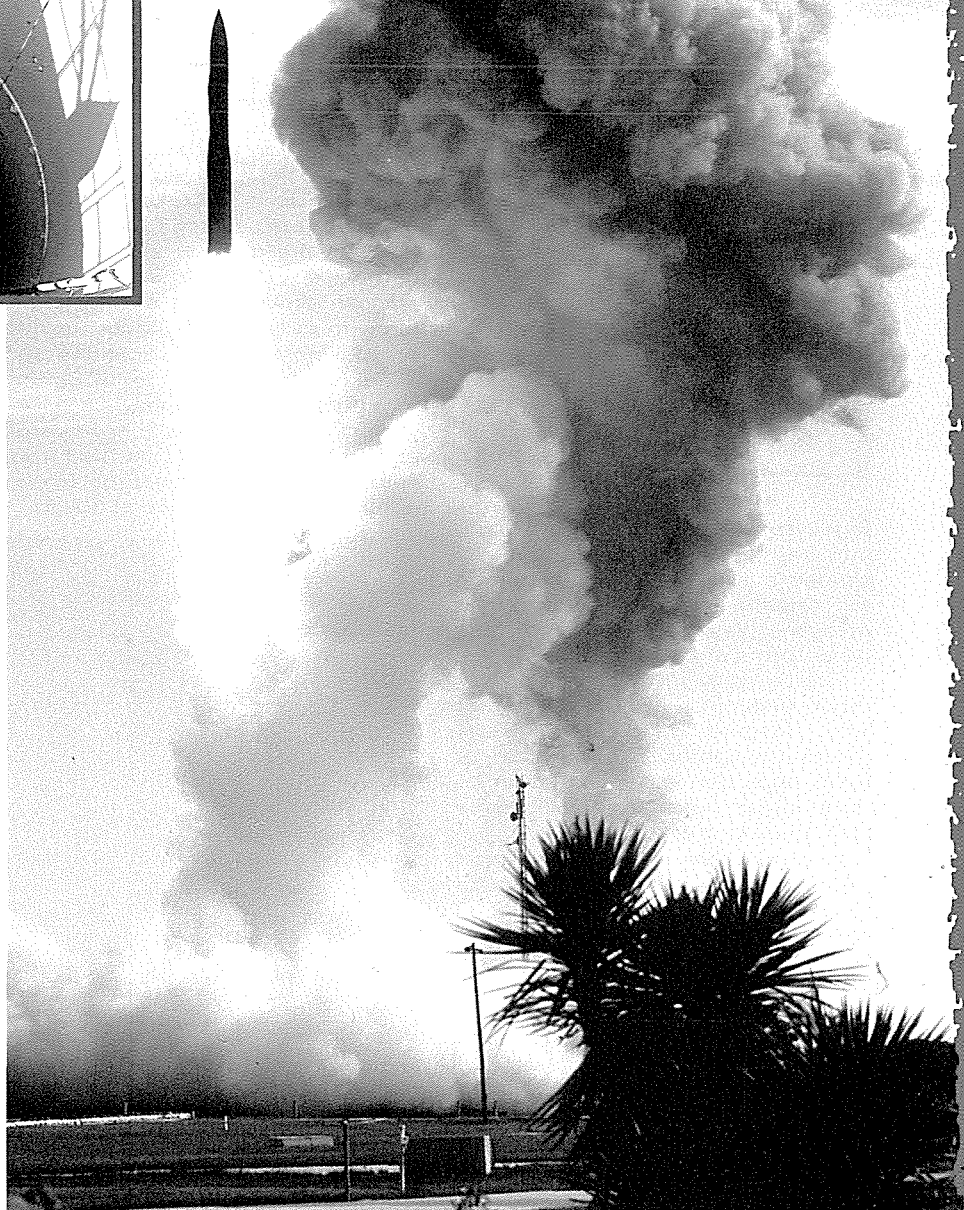
The power of a nuclear weapon is measured in terms of the amount of TNT (trinitrotoluene) it would take to make the same size of explosion. A typical 203 mm nuclear artillery shell has a power, or 'yield', of 1 kiloton, the same as about 1,000 tonnes of TNT. But the power of the larger weapons is measured in megatons – a 1-megaton blast has the same power as the explosion of a million tonnes of TNT.

The blast from an explosion goes up into the air as well as downward and along the ground, so, doubling the yield of a warhead will not double the amount of actual ground

damage it can do. A 1-megaton explosion will destroy a city area of about 50 sq km, but a 2-megaton explosion will only destroy about 80 sq km, not a hundred as you might expect.

The yield of a large nuclear weapon is often given in 'equivalent megatons'. This is the number of 1-megaton warheads required to cause the same amount of damage as that particular weapon. A warhead with a 2-megaton yield has an equivalent megatonnage of 1.6, because it will cause the same damage as 1.6 1-megaton warheads.

A single 1-megaton warhead, exploded over the Houses of Parliament in London, would totally destroy an area stretching from Brixton in the south to King's Cross in the north, and from Knightsbridge in the west to Bermondsey in the east, a total area of nearly 30 sq km.



Minuteman III takes off on test. 1,000 Minutemen stand ready in underground silos (inset) in the USA. They have three independently targetable warheads.

Since the world's nuclear powers have a total of over 20,000 megatons in their arsenals, they have the ability to inflict an unbelievable amount of damage on each other.

Nuclear explosions

All nuclear weapons can be divided into two main types – fission weapons and fusion weapons.

Fission weapons were the first to be developed. These contain heavy elements, such as uranium 235 and plutonium 239, that contain a great many atomic particles. When the weapon explodes – triggered by a charge of high explosive slamming two pieces of uranium plutonium

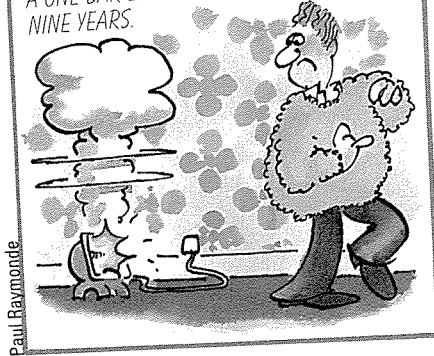
Department of Defense/USAF Boeing Aerospace Inset



Just amazing!

HI-ENERGY BAR

ON 30 OCTOBER 1961, THE USSR DETONATED THE WORLD'S LARGEST NUCLEAR EXPLOSION OF 57 MEGATONS. THE ENERGY RELEASED WOULD HAVE KEPT A ONE BAR ELECTRIC FIRE GOING FOR NINE YEARS.



together – the heavy atoms split into the smaller atoms of lighter elements and energy from within the original atom is released in a massive blast of heat, light and other forms of radiation.

Fusion weapons, also called hydrogen weapons, work in a different way. Instead of splitting heavy atoms into lighter ones, they join, or fuse, hydrogen atoms together to form larger ones. This releases a vast amount of energy.

A temperature of several hundred million degrees is needed to create a fusion reaction. In a hydrogen bomb, this temperature is created by a small fission bomb 'trigger'. The trigger is surrounded by a layer of a metallic substance called lithium deuteride – a compound

that contains the hydrogen atoms which will fuse together when the bomb goes off. Because of the high temperatures needed to make them work, fusion bombs are also known as thermonuclear weapons.

Tactical weapons

Theatre nuclear weapons are intended for use during a battle, especially one within the so-called European theatre of operations, at ranges of up to 5,500 km.

Those with a range of less than 200 km are classed as tactical or battlefield weapons. They include nuclear artillery shells and short range missiles, which can be used to attack enemy tank formations and airfields, and nuclear depth bombs for attacking submarines.

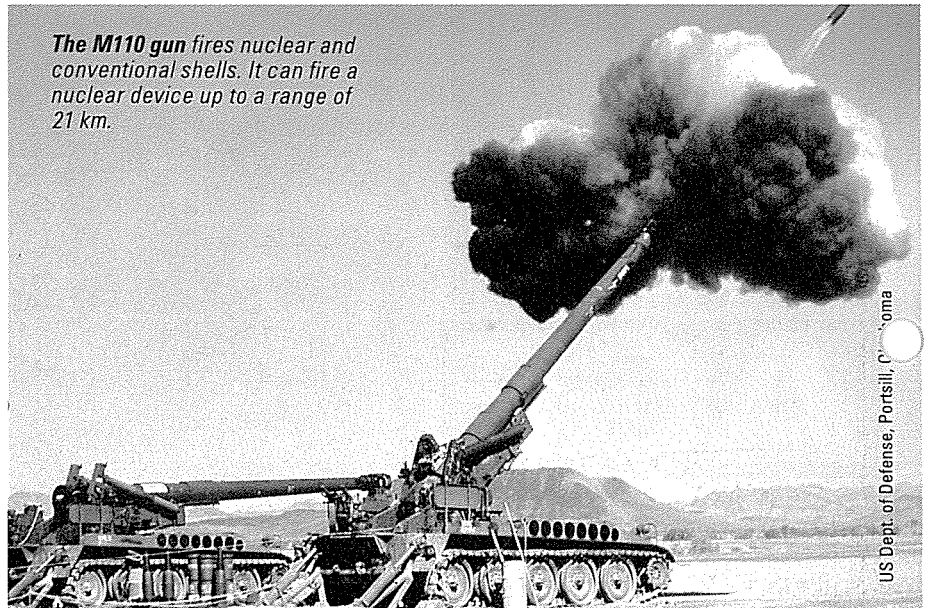
Nuclear artillery shells have yields of 1 to 2 kilotons, and are fired from self-propelled howitzers or towed guns. They have a range of 30 km.

Short-range missiles include NATO's 50-kiloton Lance, with a range of 110 km, and the Soviet Union's SS-21. These missiles can be fitted with either conventional high-explosive or nuclear warheads.

Intermediate weapons are used at ranges of up to 1,000 km, and long-range intercontinental ballistic missiles (ICBM) to 6,500 km. These categories overlap because they include bombs and shorter-range air-launched missiles delivered by strike aircraft and bombers.

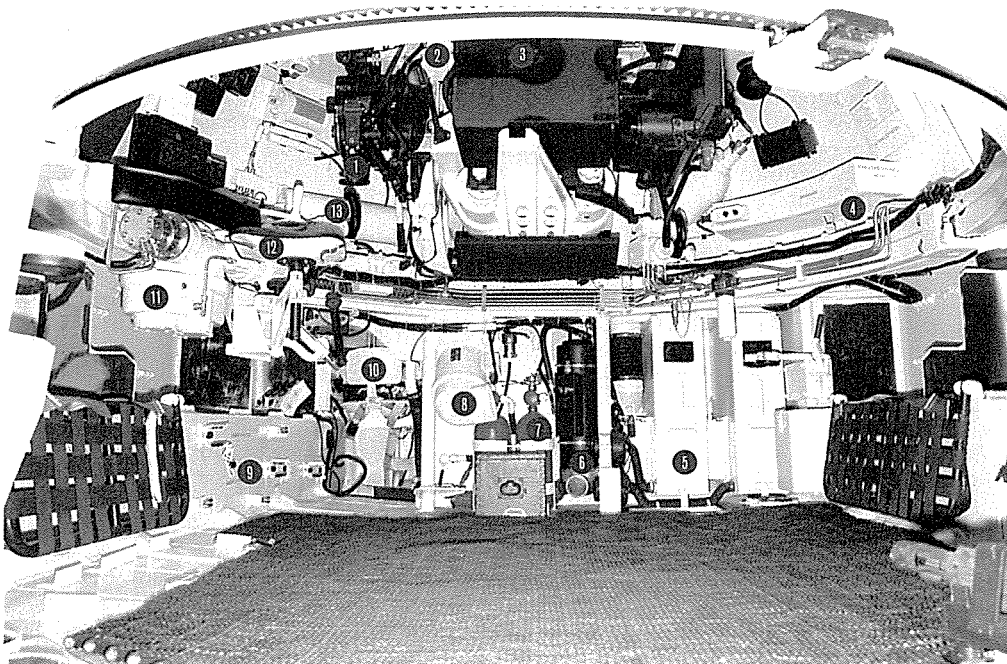
A series of arms control agreements signed by the US and Russia in 1991 and 1992 have reduced the number of tactical and strategic nuclear warheads owned by both nuclear superpowers from over 20,000 each to about 4,700 each. Certain categories, in particular land-based multiple warhead ballistic missiles and ground based cruise missiles, have been abolished altogether.

The M110 gun fires nuclear and conventional shells. It can fire a nuclear device up to a range of 21 km.



Inside the launch vehicle that bears the M110 gun. Major features include:

- 1 Dial sight mount
- 2 Elevating cylinder
- 3 Breech mechanism
- 4 Rifle rack
- 5 Engine air cleaner
- 6 Personnel heater
- 7 Fire extinguisher
- 8 Air ventilating fan
- 9 Three rifle racks
- 10 Driver's seat
- 11 Traversing mechanism
- 12 Left gunner's control



Inside a mountain in the USA, the North American Air Defense Command (NORAD) keeps watch against enemy nuclear attack.

nuclear war, this means attacking missile silos, command centres, radar and satellite ground stations, air bases, ports, and even the cities.

Strategic nuclear weapons include both bombs and missiles. The bombs are delivered by long-range bombers such as America's Rockwell B-1B, which has an unrefuelled range of up to 12,000 km. It can carry either free-fall bombs or air-to-surface missiles, or both.

The Russian equivalent of the B-1B is the Tupolev Tu-22M bomber, code-named 'Backfire' by NATO. This plane is similar in many ways to the B-1B, but it is much larger and faster. Its unrefuelled range is 17,300 km, and like the B-1B it can carry free-fall bombs or air-to-surface missiles.

Ballistic missiles

Bombers are key parts of the strategic forces of both superpowers, but the most important weapons are the intercontinental ballistic missiles (ICBMs) and submarine-launched ballistic missiles (SLBMs), most of which have multiple warheads.

Launched from underground silos, mobile land-based launchers or from submarines, ballistic missiles climb high above the atmosphere before they release their deadly warheads.

Separated from their missile 'buses', the warheads re-enter the atmosphere and fall on a precisely-calculated path to their targets.

Early ballistic missiles had single warheads, and some still do. When defensive missiles, able to destroy incoming warheads, were developed, the idea of putting several separate warheads on each ballistic missile was born.

Raining warheads

These warheads, carried in multiple re-entry vehicles (MRVs), could be released from the missile bus in a controlled sequence. There would be more chance of one or more of them evading the anti-missile defences, and the damage would be spread out over a wider target area than with a single warhead.

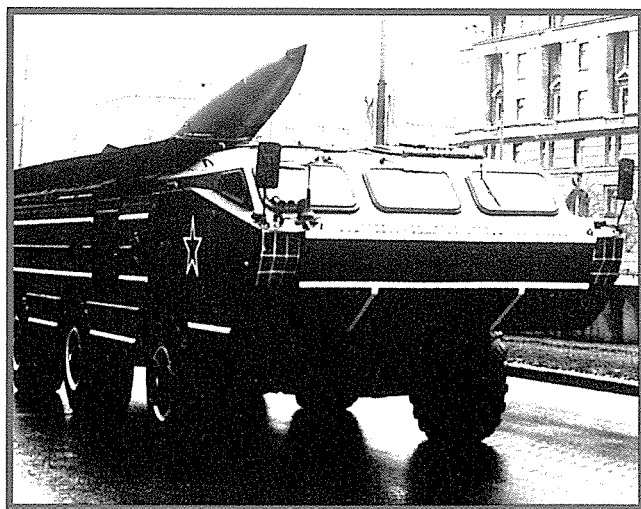
A more complex version of the MRV is the MIRV – the multiple independently-targetable re-entry vehicle. The MIRVs are ejected from the missile bus at different times and in different directions, and at different speeds, so that they travel to several different targets. Most American and Russian strategic missiles have MIRVs.

Strategic missile warheads can be adjusted to explode at different heights over their targets. A warhead targeted on a city would be detonated before it hit the ground, to spread the damage further.

However, to attack a hardened target such as a missile silo or an underground control room, it would detonate close to the ground or on

The Neutron bomb, or enhanced radiation weapon (ERW), was suggested as a battlefield weapon for attacking tanks and armoured personnel carriers.

The neutron bomb creates a smaller area of blast damage than a standard battlefield fission bomb, but it produces more 'prompt' radiation in the form of gamma rays and neutrons. The prompt radiation, which is lethal in high doses, would



kill the crews of the enemy tanks over a wider area but cause less destruction than a standard bomb.

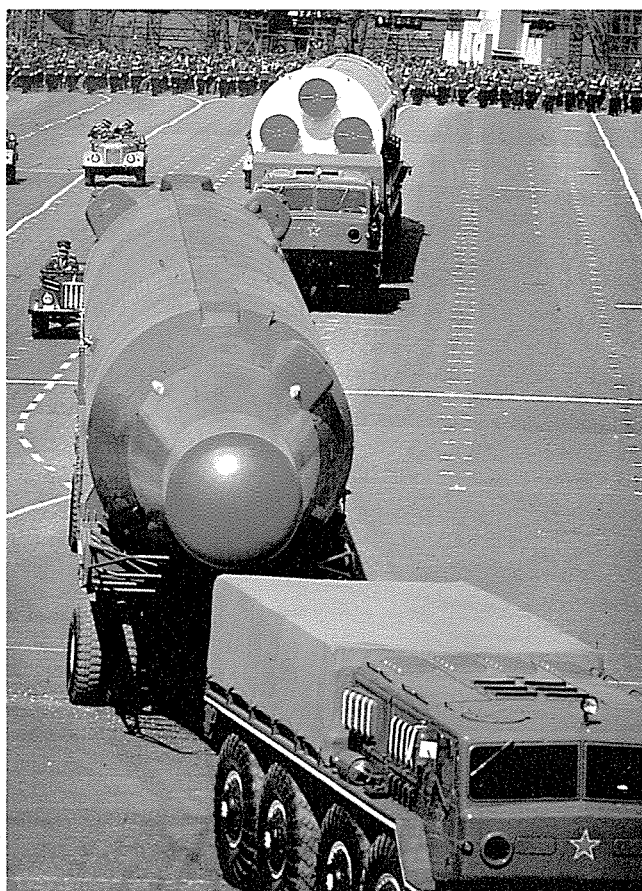
However, many experts doubt that it would really be more effective against armoured vehicles than a standard 203 mm nuclear artillery shell or a tactical nuclear missile.

Long range attack

Strategic weapons are designed to be used directly against an enemy's homeland, rather than against his troops on the battlefield. In a

The military might of the USSR was paraded yearly on May Day in Red Square. But the new Russian state has dispensed with such militarism.

The SS 21 missiles form a major part of the Russian nuclear armoury. They have a range of 120 km.



Emil Schulthess/Black Star/Colorific

ON THE SCRAPHEAP

The futility of adding to their already bursting nuclear arsenals has at last been acknowledged by the Superpowers. In the USA at Davis-Monthan Air Force base, contractors try to arrive at the quickest and cheapest way of dismantling ground-launched cruise missiles.

Special saws are used to cut through the missile storage canisters and a plasma-arc welder is used to cut through the larger parts of the missile's bulkhead. The missile is then split apart for disposal. After cutting is complete, each piece must be further cut in half before it is finally scrapped.



Gamma.Frank Spocner Pictures

difficult for an enemy to successfully launch a missile attack on a continuously moving target.

The same type of rail launcher is being used for the Russian SS-24, which is similar in size to the Peacekeeper, but much heavier at around 100 tonnes. Its range is 10,000 km, and it is armed with ten 350-kiloton MIRVs.

Department of Defense/USAF Inset TRH/USAF

impact. To make them more effective against underground targets, some future warheads could plunge deep into the ground before they explode.

The Peacekeeper

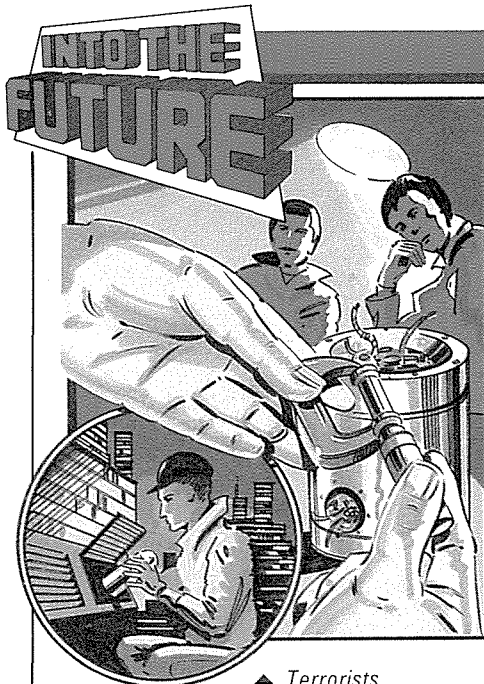
America's latest missile development is the MGM-118A Peacekeeper, formerly known as the MX. This missile, 21.6 metres long and weighing 87.5 tonnes, carries ten Mk 2 MIRVs, each armed with a 300-kiloton W87 warhead. It has a

The ten re-entry vehicles of a Peacekeeper missile pierce their way through clouds, bearing their lethal warheads (inset).

maximum range of 14,000 km.

The first ten Peacekeepers are deployed in silos previously used to house Minuteman III missiles, but the rest are to be mounted on special railway trucks.

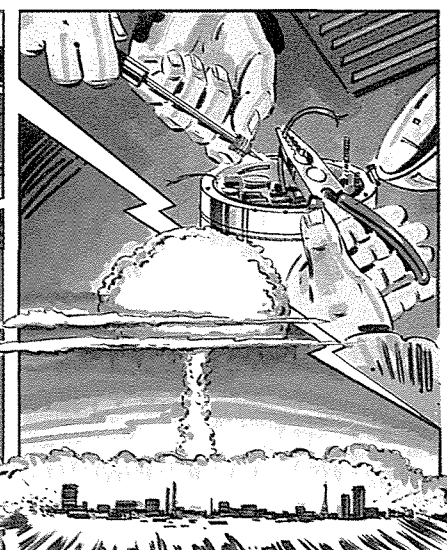
The advantage of using mobile launchers, such as trains, is that unlike fixed silos whose positions are known accurately, it is very



▲ Terrorists would be able to make a small nuclear bomb from black market plutonium and hide it to use for bargaining.



▲ Negotiations would be extremely delicate and would have to be kept top secret. The slightest news leak would cause untold chaos and panic.

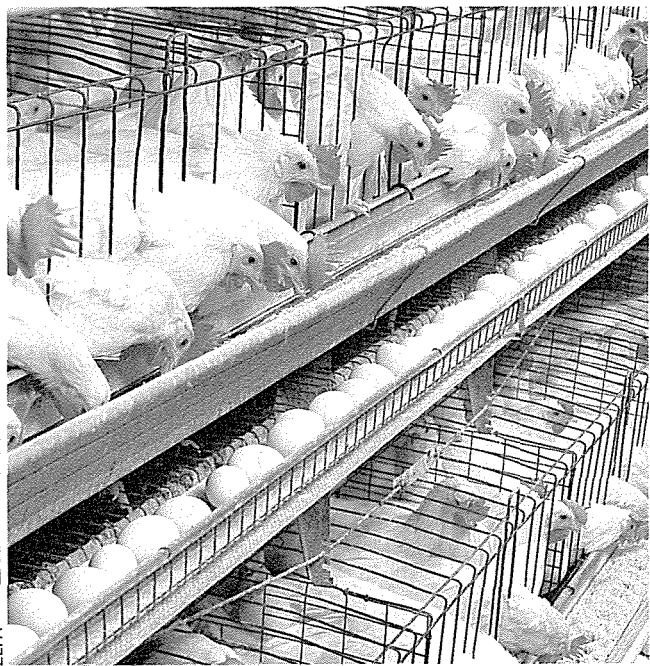


▲ Should the negotiations be successful, the bomb could be defused. But if negotiations broke down or failed, the consequences would be incalculable.

Lawrence



INTENSIVE FARMING



-  AUTOMATION
-  LIVESTOCK
-  POISON BAITS

Young chickens live in a broiler house (below) when reared for their meat. Laying hens are kept in wire cages (left). Their eggs roll to the front of the cage and their droppings fall through the floor.



SCIENCE AND TECHNOLOGY are playing an increasing role in farming as it becomes more and more intensive. In livestock farming, intensification improves productivity of meat, eggs, and milk by increasing the numbers of animals supported by available land. It also reduces the amount of labour required for management and increases the productivity of the individual animal.

When the numbers of animals on the land are increased, it creates problems. Livestock can no longer support themselves by grazing or foraging, and must have expensive supplements or manufactured

feeds. Disease is often a problem, and diets and housing techniques are often adapted to minimize this. Disease is also a major threat to arable farming. So fields are often sprayed with chemicals to prevent disease and also to control pests that eat the crops.

Pest control

Pests include animals that attack crops and also those that attack farm animals and man, often transmitting disease organisms to them. About a quarter of the world's food supply is consumed or destroyed by pests, mainly insects, worms, rats and mice. Much sickness and disease is spread by pests such as mites, ticks, mosquitos, tsetse flies

and snails. Other prevalent pests include birds, millipedes, woodlice and slugs.

Indirect ways to control pest attack include crop rotation and choice of crop variety to avoid attack. Crop rotation is most effective against relatively immobile pests, insects that over-winter in the soil, and pests that attack only one particular crop.

Direct control

Poison baits, seed treatments, and sprays, dusts, or granules containing potent pesticides are various means of direct control. For pests in soil, warehouses and buildings, fumigants are normally used. These are usually liquids but sometimes

Waller/Jerrican

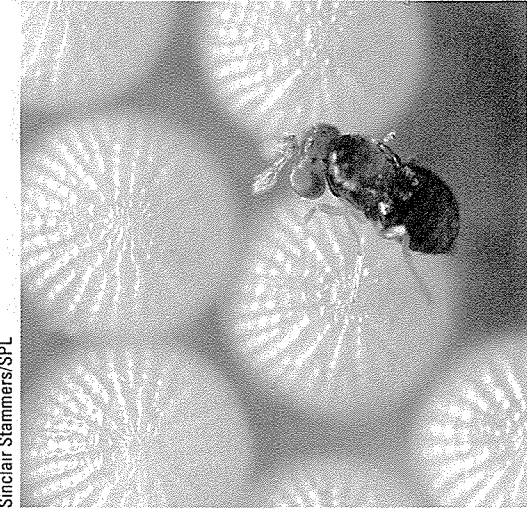




Grain storage containers range from small bins to huge concrete buildings with built-in equipment for filling, emptying, weighing, drying and blending the grain. The storage shown here has a tilting platform for emptying truckloads of grain rapidly.

BIOLOGICAL CONTROL

A species of wasp is put on some crops to prevent them from being eaten by caterpillars. The tiny female chalcid wasp pierces the eggs of the cabbage moth and lays her own eggs inside. The moth eggs never develop into caterpillars because they are eaten by grubs that emerge from the wasp eggs. This technique, a form of biological pest control, is widely used in China.



Sinclair Stammers/SPL

powders, which vaporize and spread themselves throughout the infested area. In glasshouses, smoke canisters and aerosols may be used.

Spraying, dusting and granule applying machinery cannot pass through tall or mature crops, so these must be treated from the air. Fixed-wing aircraft are cheapest for large areas, but helicopters have several advantages. They are more manoeuvrable, do not require landing strips, and the downdraught they generate helps to force pesticides into crops.

Because rats and mice are wary, unpoisoned bait is first offered. When the rodents are feeding free-

ly, poison bait is substituted.

The numbers of most pests are limited by naturally occurring enemies. For example, ladybird beetles feed on greenflies, ichneumon flies lay eggs in the young of many insects. And predatory beetles and spiders kill various pests. Unfortunately, some pesticides kill many of these beneficial species, resulting in an increase of other pests. The red spider mites have increased greatly since orchards were sprayed to control various pests and diseases, mainly because spraying kills their principal enemy, the red-kneed capsid.

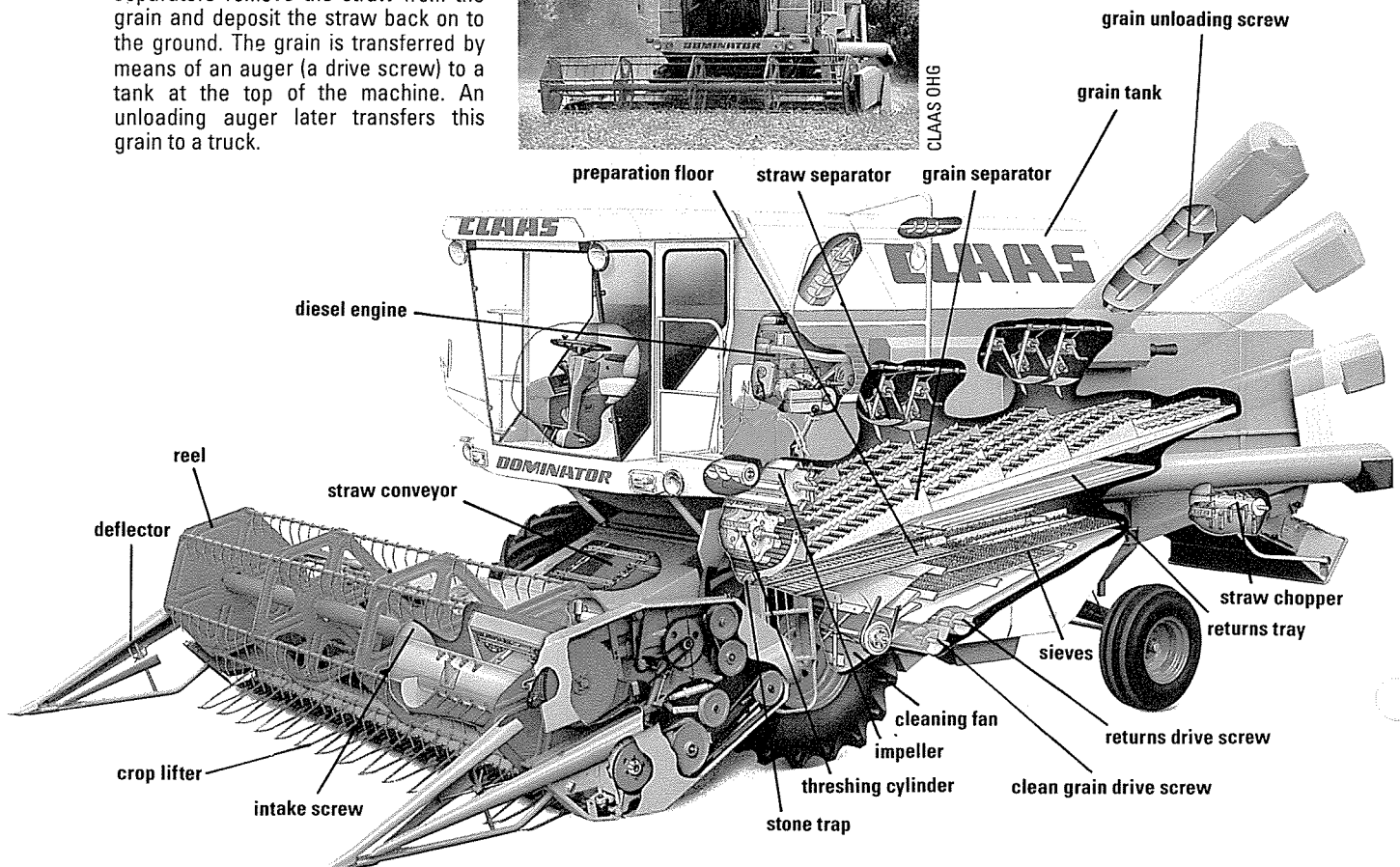
To avoid these problems, scientists are trying to decrease or eli-

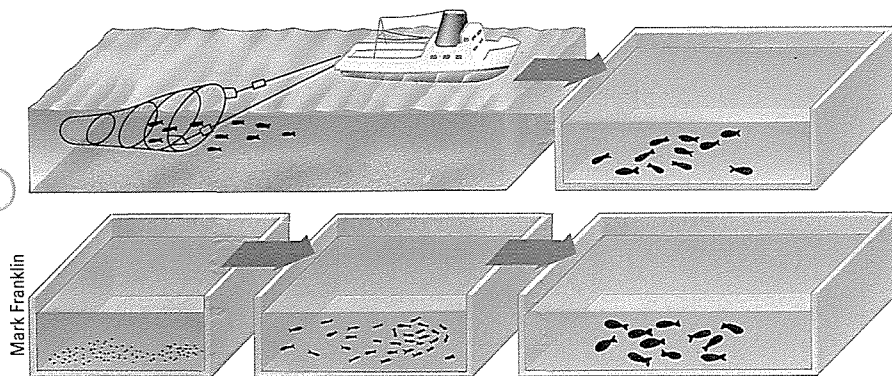
THE COMBINE HARVESTER – A MULTI-PURPOSE MACHINE

The combine harvester is used first to reap the grain crop and then thresh it to knock the grain from the straw. Grain separators remove the straw from the grain and deposit the straw back on to the ground. The grain is transferred by means of an auger (a drive screw) to a tank at the top of the machine. An unloading auger later transfers this grain to a truck.



CLAAS OHG





Mark Franklin

Fish farming takes many forms. The young fish may be caught at sea (top) and transferred to tanks on land. There they can be fattened until ready for market. Another method (above) is to hatch and mature the fish in a series of tanks.

SALMON FARMING

Salmon is a luxurious fish, prized for its delicious flavour. The great demand for this fish has led to the development of salmon hatcheries. Salmon are more difficult to farm than other fish as they live partly in the sea and partly in fresh-water streams and rivers. Some months after hatching in fresh water, the young fish swim to the sea, where they grow into adults. In a hatchery, the female salmon lays her eggs in fresh water. The fry (young fish) are first confined to a stretch of river. They are later transferred to the sea, where they are kept and fed in netting enclosures or cages. It takes about three years to produce a 9 kg salmon from the egg.

minate pesticides and encourage the natural enemies of the pests. In biological control, natural enemies such as predators, parasites, fungi, bacteria, or viruses are used to control pest species. These techniques have met with some spectacular successes.

One of the newest forms of biological control is the use of insect hormones. If the right insect hormone is synthesized, it can be used to interrupt that insect's life cycle at a critical stage and thus lead to its extermination. Because the hormone affects a system peculiar to one type of insect, other creatures are unaffected.

Fish farming

In nature, only a fraction of one per cent of the eggs that are spawned by most species ever survive to become fish of marketable size. Fish farms, however, produce a much higher yield.

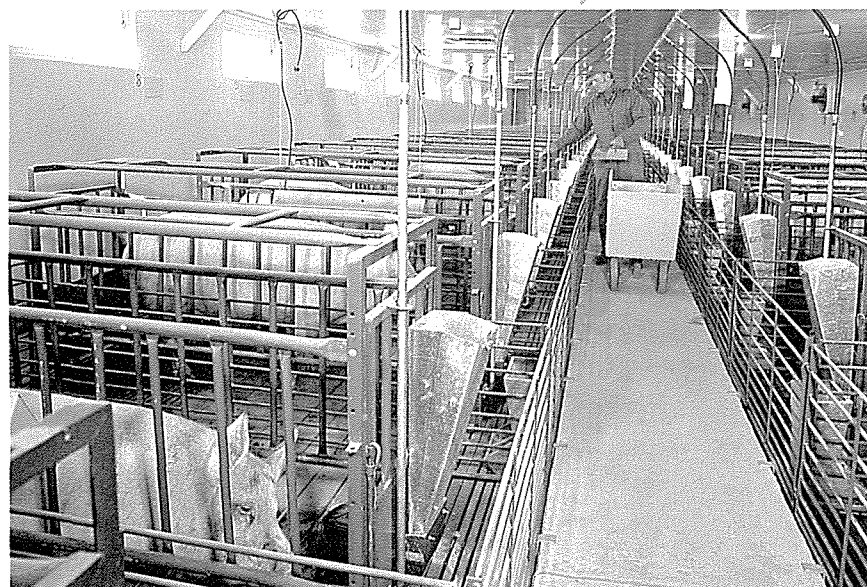
Fish farming, or aquaculture, takes many forms. Some trout farms are elaborate complexes of concrete raceways, pumps, aerators and equipment to remove

waste products and excess nitrogen from the water, and restore oxygen and acidity so that the water may be recirculated. Some species can live in virtually stagnant water with much plant growth, because they require comparatively little oxygen and their diet consists of vegetable matter and small aquatic life.

Cold-water species, such as trout, require clear, well-oxygenated water, and the commercial rearing of carnivorous species like trout, salmon, eels, turbot and sole depends upon supplies of feeding stuffs containing a high proportion of animal protein. One source of feeding stuffs is fish of species difficult to sell for direct human consumption.

Maximum meat

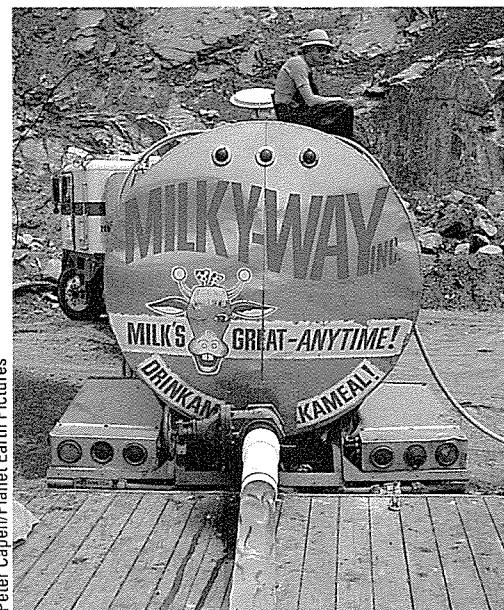
In all intensive systems, animals producing eggs or milk or being fattened for meat production, are separated from the breeding stock. Maximum meat productivity is achieved by selective breeding to produce as many offspring as possible. Breeding has also changed the appearance of farm animals. For example, today's pig is a streamlined meat machine far different from its hardy, bristly ancestor. It is the end result of breeding that has drastically changed the animal's shape to suit the public demand for lean meat.



ZEFA

The pig has been adapted so well to its new role that half the meat eaten in the world comes from pigs.

Growth rates slow as animals near maturity, so livestock is usually slaughtered while still relatively young. By doing this, the food consumed by the animals is converted to the maximum possible weight of flesh. To raise them until they are fully grown would require a disproportionate quantity of feed. For example, a broiler chicken reaches a weight of 2 kg in seven



Peter Capen/Planet Earth Pictures

Small live fish are transported by road to and from fish farms in tankers. The water and fish are simply pumped up into the vehicle through a large-diameter pipe.

Modern pig-breeding units have narrow stalls in which the pregnant sows are often confined for most of the time. There they produce litters of about ten piglets. Most sows have two litters every year.



A modern milking parlour has electronic equipment to recognize each cow's identification tag. A message on a computer screen then informs the herdsman of any special checks or treatment required. For example, the milk may have to be tested for drugs if the cow has had medical treatment.

Mustering cattle by helicopter saves valuable time on the vast ranches of Australia.



modern pig-feeding system, for example, includes a large mix tank, a feed pump and electronic weighing units. Many different feed ingredients, solids and liquids can be mixed and delivered in programmed quantities to exact requirements with no wastage. Timers release the mixed feed two or three times a day through pneumatically operated feed valves into troughs in the separate pens. Each pig or group of pigs receives exactly the amount previously calculated and keyed into the control box, and it can take as little as seven minutes to feed 400 animals.

Free range farming

In recent years many people have begun to question some of these modern livestock farming methods. It is claimed that some types of factory farming are cruel and cause unnecessary suffering to the animals.

Several farmers have begun keeping their animals in 'free range' con-

ditions. This means that the animals have plenty of space to move about, usually in the open air. They find much of their food themselves, the diet being supplemented only with specialist foods or during the winter.

Meat, eggs and dairy products produced by these methods are labelled as free range. They usually cost more than factory farmed products, but often taste better. The customers who choose to purchase free range products may do so because they wish to be certain that no animals have suffered needlessly, though some factory farm techniques are equally humane.

Slaughter

In developed countries, methods of slaughtering farm stock are regulated to minimize the animals' distress and pain. A common method is to stun the animals first with an electric shock, so that they feel no pain. Then their throats are cut and they bleed to death.

Pig carcasses are blast-frozen to 0°C, then gutted and split using chain saws. After weighing the carcasses, electronic probes measure their meat and fat content. About 40 per cent of the edible part of the body is used for bacon. The rest is cut into fore-ends, middle gammon, loin and belly.



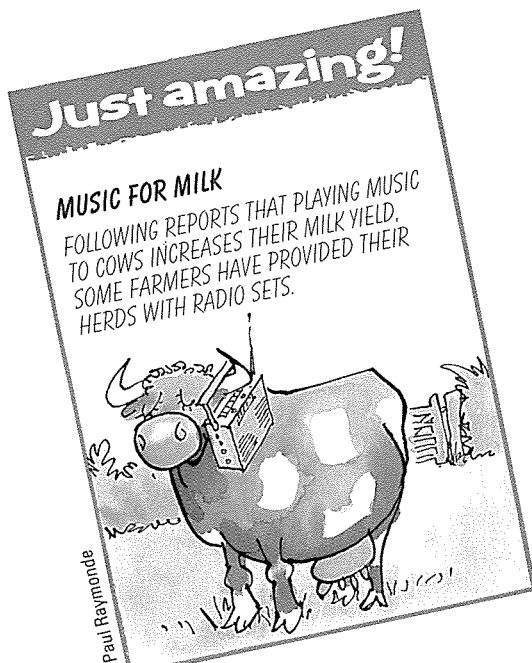
Meat & Livestock Commission

weeks, when it is normally killed. For each 1 kg of feed it consumes, it gains 0.45 kg in weight. But if it is allowed to grow to a large size, it will soon take 1.4 kg or more of feed to put on the same amount of extra weight.

Food and drugs

In animals growing at such a rapid rate, nutritional requirements continually change, and very careful control of feed ingredients is necessary. Growth rates may be further stimulated by supplementing the diet with growth-promoting substances, such as antibiotics.

With so many animals in an intensive farming unit, part or all of the feeding process is automated. A



DESTROYING ORGANISMS

DEHYDRATION

FREEZING FOR FRESHNESS

PROCESS

FOOD PRESERVATION

Over 1000 cans per minute can be processed by being heated in a large capacity, pressurized vessel at temperatures above 100°C

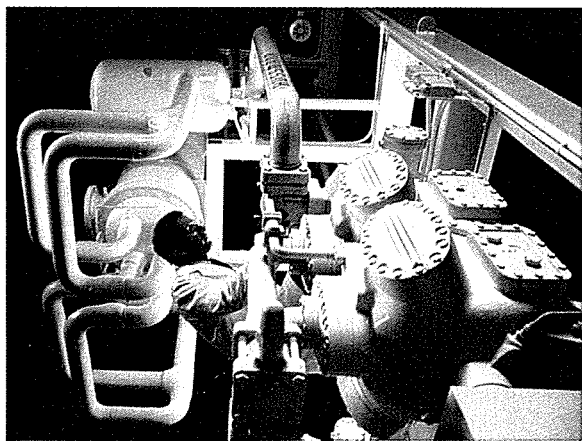


Image Bank

Carcasses are cooled rapidly from 30°C to 10°C in a refrigerated unit (inset), then chilled more slowly to 1°C to prevent the meat from becoming tough. The chilled fresh meat is stored in a chiller at 0°C, 85–90 per cent humidity, with spacing between carcasses to ensure good air circulation.

THE RANGE OF FOODS available on supermarket shelves has grown rapidly during the last decade, but all forms of food preservation are still based on only two principles.

One is to destroy, deactivate or remove those elements that cause food to spoil. The other is to create conditions that inhibit these elements within the food.

Micro-organisms such as yeasts, moulds and bacteria account for

much food spoilage. Heating can destroy organisms and deactivate enzymes – unfortunately, it can also cause unwelcome changes in colour, flavour, texture and nutritional value.

Heat treatment

Generally, heating food rapidly to a high temperature, maintaining the heat for a short time, then cooling it quickly – the high-short process – results in less loss of quality than



heat processes involving lower temperatures for longer times.

Sterilization is a relatively severe heat process which kills nearly all the micro-organisms in food. The commonest method of sterilizing food is to seal it in a container, which is then heated in a pressure vessel, or retort, by means of pressurized steam. Temperatures used are in the range 100–126.5°C for times ranging from 10–90 minutes, depending on the type of food and the size of the container.

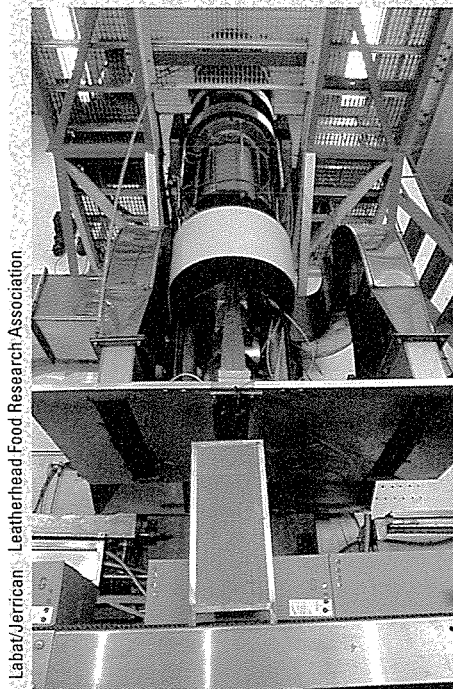
Pasteurization

This is a more gentle process of preservation, which kills all food-poisoning organisms and micro-organisms, but only some of the organisms which make food go rotten. This makes food safe to eat, but it will deteriorate in a relatively short period. Pasteurized food is heated to temperatures below 100°C and maintained hot for specific periods of time, depending on the type of food.

Drying processes

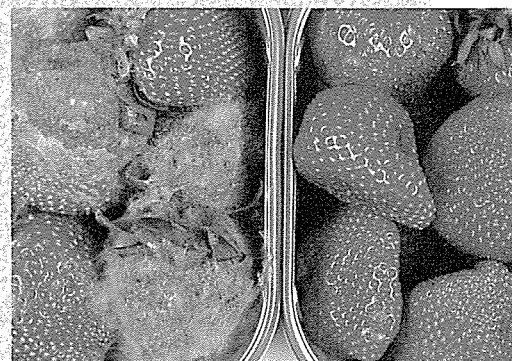
Micro-organisms need moisture to survive and remain active, and moisture is also essential for many of the chemical changes that occur in foods. Drying removes most of

PRESERVING FOOD WITH GAMMA RAYS



Leatherhead Food Research Association

In an irradiation plant, food is carried on conveyor belts through an irradiation room where it is bombarded with gamma rays given off by cobalt 60 and caesium 137. The rays sterilize the food but the dosage is too low to make the food itself radioactive. Below right: irradiation strawberries; below left: untreated berries. Irradiation can extend the shelf life of fresh foods by retarding spoiling. Large-scale potato irradiation is practised in the USSR and Japan.



Milk is sterilized in bulk, then put into pre-sterilized cartons which are quickly sealed under bacteria-free conditions.

increased to 65 per cent, a mild heat treatment gives increased preservation. Heat damage during concentration is minimized by boiling off the water at reduced pressures.

Freeze-concentration has been applied to fruit juices, coffee and tea extracts. After freezing the liquid food, ice crystals are separated from the remaining liquid. The partly concentrated liquid is frozen again, then the ice is removed, leaving a highly concentrated liquid with no heat damage.

Freezing inhibits the activity of micro-organisms and slows down chemical changes. Blast freezing is one of the fastest freezing processes. A blast of air cooled to a mean temperature of -30°C is usual.

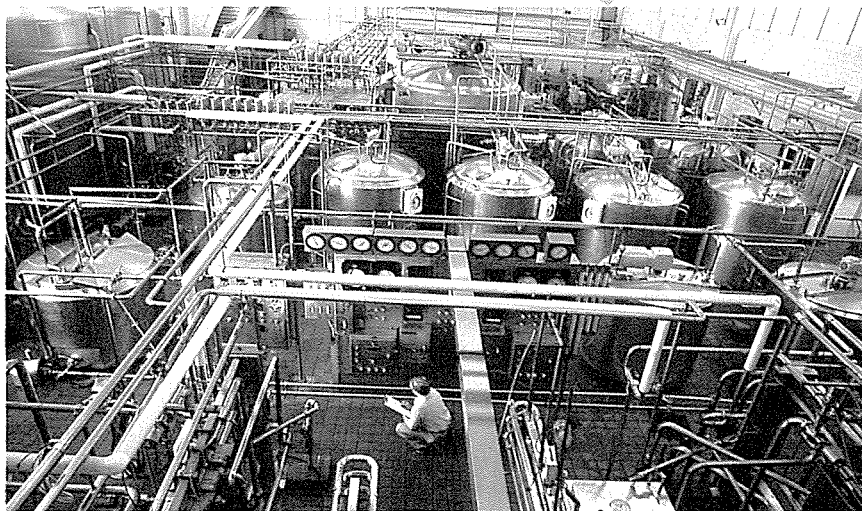


Image Bank

the moisture, and this prevents the food from spoiling. Fruits, vegetables and some meat products are dried by heating in hot-air cabinets or tunnels.

Liquid foods, such as milk and coffee, are sprayed as a fine mist, which is mixed with heated air in a large drying chamber. The spray dries rapidly to form a fine powder, which may form lumps when spooned into hot liquid because the powder is so fine. To solve this problem, the spray-dried particles are re-wetted and brought into contact with each other so that they form clusters of larger-sized particles. When re-dried carefully, the clusters disperse and dissolve quickly in liquids.

Some foods, such as fruit juices

and some fish and meat products, are damaged if heated strongly. Heat damage is minimized by heating these foods inside a vacuum cabinet, which enables the water to evaporate at lower temperatures.

Freeze-drying is a further development of vacuum drying. The food is frozen, then dried by being heated in a vacuum chamber. The ice changes directly to vapour, with no intermediate liquid stage. The result is a light porous solid, which keeps its original shape, picks up moisture rapidly when reconstituted and has a good colour, smell and flavour.

Concentration is another means of preserving liquid foods. If the proportion of soluble solids in acidic foods (such as jellies and jams) is

Just amazing!

DEEP-FROZEN SAILOR

FREEZING DOESN'T PRESERVE JUST VEGETABLES – A PERFECTLY PRESERVED SAILOR WAS UNEARTHED AFTER BEING BURIED IN ICY GROUND FOR 139 YEARS.



Paul Raymond



HIGH PERFORMANCE EQUIPMENT



Rowing simulators use computer software to produce sound effects; the TV screen displays a pace boat to encourage greater efforts.

SCIENCE AND TECHNOLOGY can help sportsmen in many direct ways. For example, carbon fibre golf club shafts can add 20 or 30 metres to the drive of an amateur golfer, without any extra effort or skill on his or her part.

Technology can help indirectly by systemizing traditional training methods through the use of machines.

Weight training machines come in many different forms. Simple pulley designs allow the user to work through a full range of movement, in relative safety. Most pulley machines allow you to exercise one muscle group at a time (single station), yet it is possible to group several single station units together to form a multi-gym.

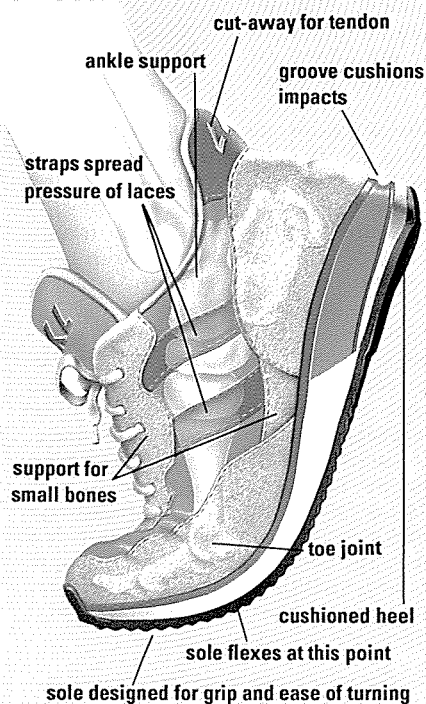
More sophisticated exercise equipment makes training more efficient through the inclusion of a non-uniform pulley which is known as a cam. It is known that muscles can produce more or less force according to their length, position, speed of contraction, type and the nature of the joints at which they act. Cam-based machines, such as Nautilus, try to take these factors

DESIGNING A RUNNING SHOE

The human foot is a very complex and delicate structure, with lots of small bones that can be forced out of place or broken if too much stress is placed on them. Sports shoe designers aim to take some of the load off the foot by matching the bending characteristics of their shoes to the bending characteristics of the human foot. They also suit the design to each specific sport.

This can't be done by studying the foot at rest – shoe designers need to know exactly how the foot hits the floor, the various positions taken up by the foot throughout the sequence of running actions and the exact relationship between the ankle and the foot.

The basic information is gathered by recording the running action of some typical runners using high speed filming techniques. Next, each part of the foot to be studied is labelled and transformed into a series of numbers that define each position on a digitizing table. When all this information has been gathered, it is fed into a Computer Aided Design (CAD) system and displayed on a VDU. Working on screen, the designer uses his knowledge and experience to produce the ideal shoe.



Action Plus

Chris Lyon



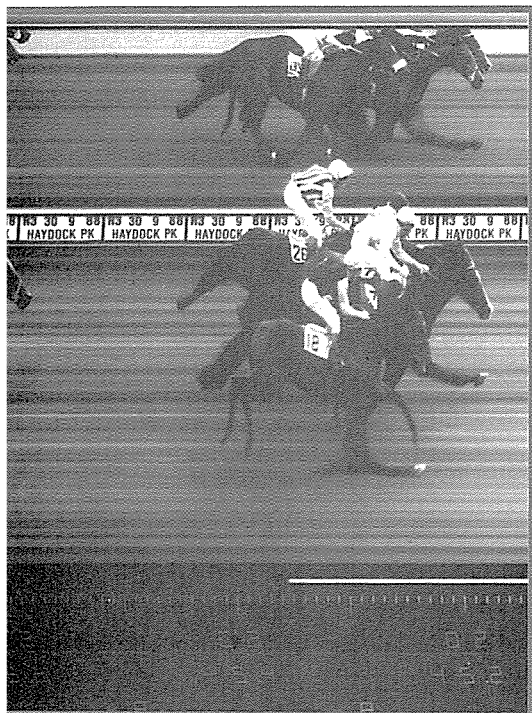


Photo-finish
pictures record the
time on a strip
along the bottom of
the picture.

Racecourse Technical Service

Two cameras
take shots from
different angles,
which ensures that
the winner can be
picked out easily.
The film is moved
past the lens when
the runners get
near the finish.



into account since the machine's cable or chain, as it runs over the cam, effectively ensures that the load the exerciser is overcoming is constantly changing. Cams match as closely as possible a muscle's 'strength curve' so that the training effect is maximized.

The most recent designs in exercise equipment have seen the introduction of hydraulic cylinders and even electro-magnets instead of weights to provide the resistance. Some of the latest machines also feature computer software, which allows them to be programmed with basic information about the user, before giving the appropriate training programme and sequence. Such machines also 'talk' to you, urging you to work harder!

Analyzing performance

Small differences of technique can yield big improvements in performance. The parts of the body that the coach wishes to study are labelled

on a computer and the position at any given moment is recorded numerically. Another computer program then turns this information into a line diagram of all the movements; if necessary, variations in technique can be punched into the computer to see what effect they have on body position and predicted performance.

Artificial surfaces

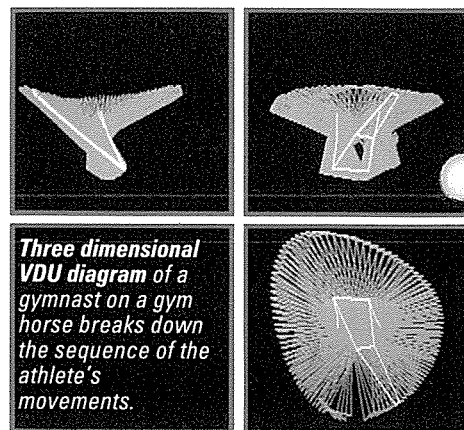
Ordinary grass pitches and running tracks tend to turn to dust in the summer and to mud baths in the winter. For running and other sports, such as hockey, one solution is an artificial playing surface. The best types have a top layer of resilient polymer and are laid on an asphalt base incorporating drainage pipes. The polymer has sufficient 'give' to help prevent strains and jarred muscles; spikes do not damage it, so it can also be used for running tracks.

Using artificial surfaces for football pitches has not been success-

ful, for several reasons. They resulted in an unacceptable number of injuries because, when a player swivelled, the foot tended to stay in the same position, putting enormous strains on the knee joint. Players also suffered skid burns and abrasions if they slipped or fell. In addition, the football itself tended to bounce very high on the artificial surface, which shifted the game away from passing and running and much more towards heading and volleying.

Computerized timing

A man with a stop watch cannot time accurately down to thousandths of a second – but this is comparatively easy using a computer system. The starting pistol or starting horn is fitted with a transducer which detects the sound made when the starter pulls the trigger. The transducer is connected by wire to the timing computer which starts to count immediately it



Three dimensional
VDU diagram of a
gymnast on a gym
horse breaks down
the sequence of the
athlete's
movements.

receives the signal from the transducer.

At the finish the signal for the computer clock to stop is given by two parallel infrared beams in line with the finish. Two parallel beams six inches apart are used to prevent a stray arm or leg registering the finish: the whole body must pass through both beams before the clock is stopped. The time is printed out on a small slip of paper; it can also be displayed on the computer read-out and on a large read-out for the public.

Photo-finish camera

The photo-finish camera is vital in horse racing, track cycling and similar events, where lots of competitors may pass the winning post at almost the same moment.

The camera is installed exactly in line with the winning post. A special lens with a large depth of field is used at the front of the camera, but instead of the normally circular aperture through which the light reaches the film, there is a narrow slit. Events are recorded in the order in which they happen, so the winner is the one in front on the film.

The best artificial playing
surfaces are laid with a purpose-
built machine that prepares the
compound as it travels along, so
eliminating seams. A laser head
controls the surface level.

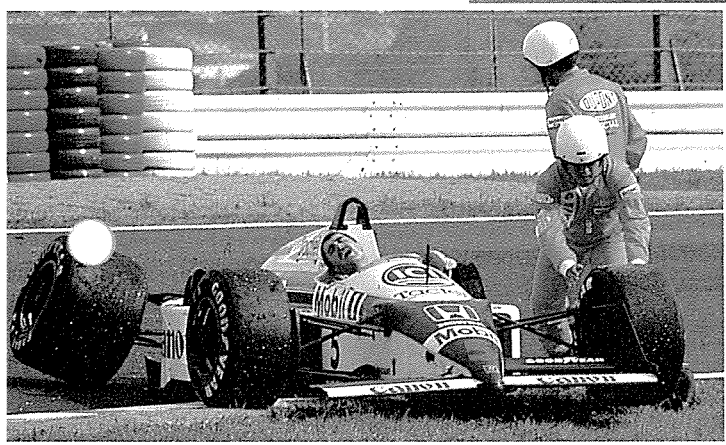
C Voight Söhne/Rekortan



POWER SPORT



-  CARBON BRAKES
-  STEPLESS GEARS
-  CERAMIC TURBOS



Colorsport

Colorsport

WINNING A MOTOR RACE, whether it's Formula 3 for beginners or Formula 1 for the title of World Champion, is a matter of getting a lot of engineering details exactly right, then blending them together into a winning design.

The regulations for each category of race lay down whether or not turbochargers are allowed, the maximum size of the engine, details of the bodywork and the overall maximum weight of each car. But within the scope of these regulations, the biggest influence on winning or losing is the amount of power that the engine produces. Engine output depends, among other things, on:

- Feeding the correct proportion of air and petrol into the engine, depending on the conditions
- Igniting the mixture at just the right moment
- Designing a combustion chamber in which the mixture burns well and so develops the maximum possible pressure (around 2,000 pounds per square inch)

acting on the piston

- Enabling the exhaust gases to leave the cylinder as quickly and completely as possible, so leaving room for the maximum amount of fresh mixture to be drawn into the engine next time round.

Pumping losses

Until relatively recently the petrol/air mixture was simply sucked into the engines. But some engine power is used to suck the air in and pump the exhaust gases out of the engine. These losses are known as 'pumping losses'. To minimize this loss, many engines used in endurance racing and in rally cars now use a turbocharger.

This is an air pump powered by the energy in the escaping exhaust gases; it increases the pressure at which the petrol/air mixture enters the engines. The higher pressure ensures that the cylinders are completely full at the start of every power stroke, so a turbo racing engine produces more than twice

Racing drivers have to keep 650 horsepower under control. Even in dry conditions, the cars go out of control; when it is wet, dangers are multiplied – especially at the start when the track is crowded.

as much power as an ordinary one. Winning Formula 1 engines have produced up to 1,200 horsepower.

Ceramic turbos

Some of the latest racing cars are fitted with a turbocharger using a lightweight turbine made from ceramic rather than metallic material. This is similar to the porcelain used for making cups and saucers – but much, much stronger. As a result, the engine power builds up much more smoothly, which makes the cars much easier to drive in the heat of a race.

Microprocessor-controlled engine management systems also make life easier for racing drivers. One large electronic chip controls the pressure generated by the turbo, the fuel/air mixture and the timing





RENAULT V10 FORMULA 1 ENGINE

Renault have built a ten cylinder, Formula 1 engine that complies with the new regulations. It has two banks of five cylinders in a vee-formation to keep the engine short and so make it as easy as possible to fit into a car. Design and manufacture of the exhaust system is a major problem because it has to snake past the rear suspension and gearbox (inset below).

Renault

bank of five cylinders with twin overhead camshafts

fuel injection

air trumpet

fuel line to injector

fuel injection pump

cam covers

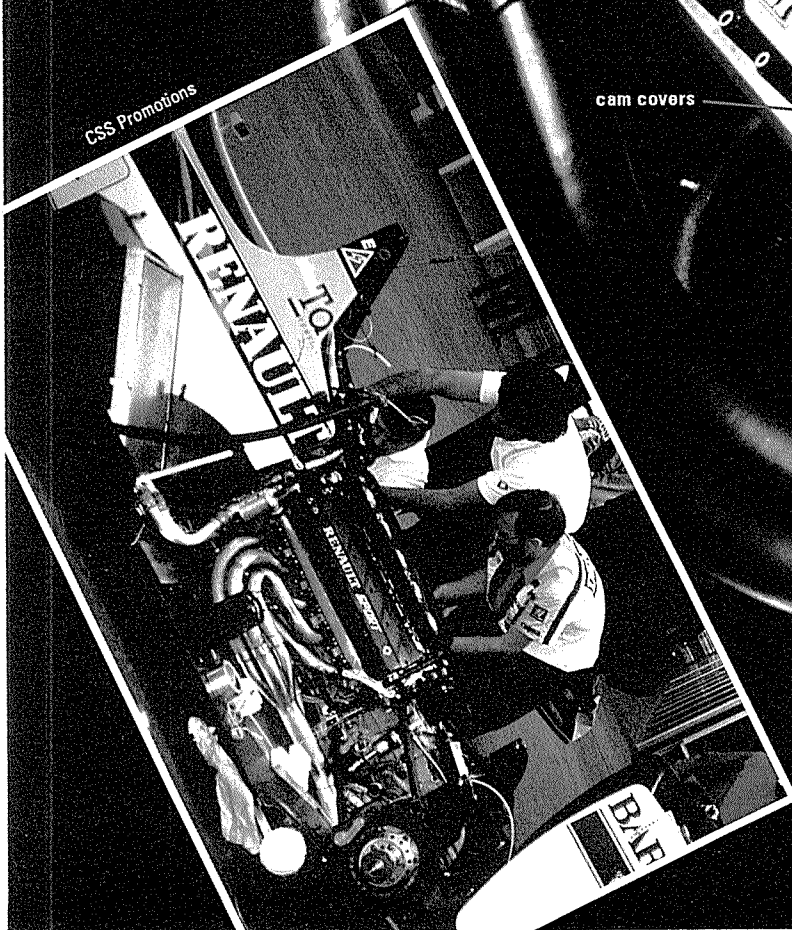
camshaft drive

alternator drive

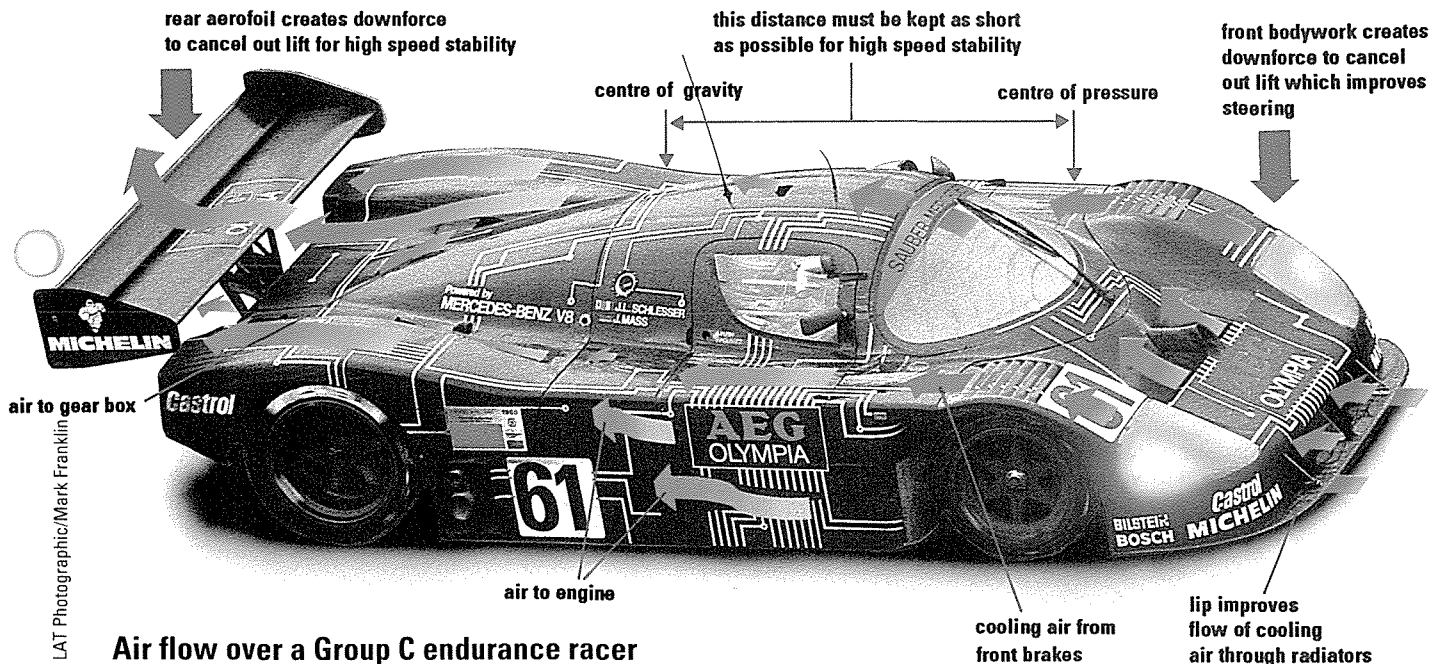
oil pump drive

5 into 1 exhaust system

toothed belts



CSS Promotions



Air flow over a Group C endurance racer

of the spark that sets off the combustion process. Again, this smoothes out the power delivery so that when a driver puts his foot down, the engine responds without hesitation.

But there are problems with turbos, so at the end of the 1988 Grand Prix season, the small but powerful 1.5 litre turbo engines were banned. They have simply become too powerful for the drivers to control safely, and too expensive to design and build. In their place, Formula 1 engines will have 3.5 litres capacity and up to 12 cylinders instead of the four or six

cylinders of the 1.5 litre engines. To extract the maximum power from these engines, designers are experimenting with 5-valve cylinder heads, and intake and exhaust systems that are carefully tuned to maximize gas flow, and variable-timing for the camshafts.

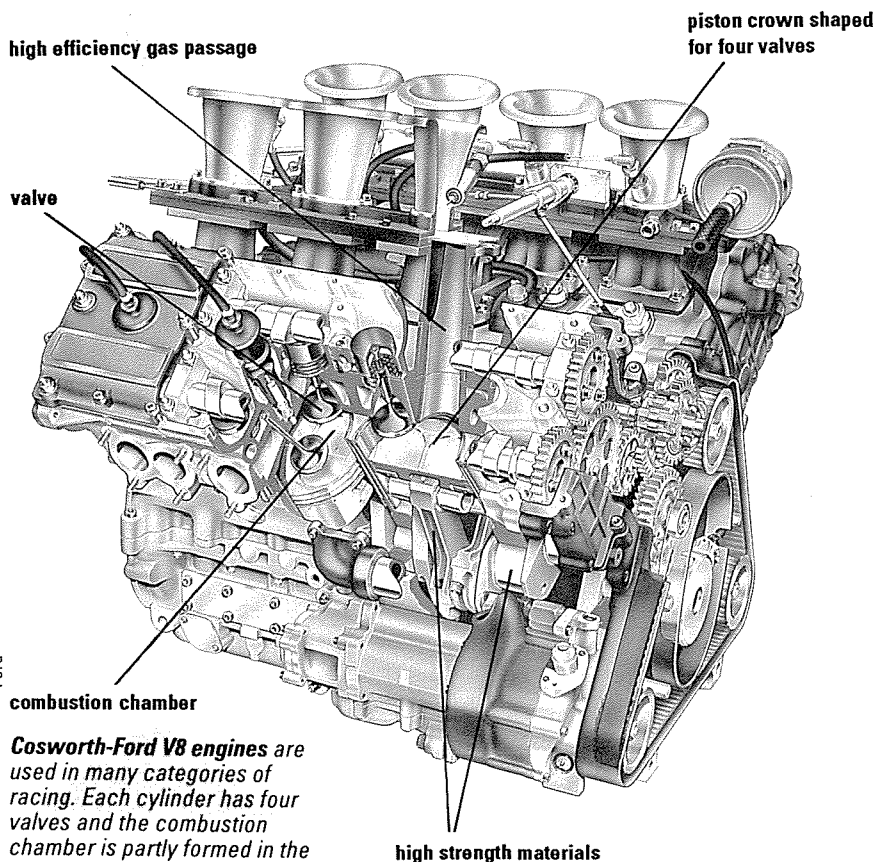
CAD methods

Computer-aided design methods enable racing car designers to work out exactly where strength is needed in engine, suspension and body components. With this knowledge, they can design lighter, stronger, faster cars.

Formula 1 cars must have open wheels but Group C long-distance cars are fitted with all-enveloping bodywork. This is designed in the wind-tunnel to cancel out lift and allow cooling air to reach brakes, driver and radiators.

In the case of engine blocks, the strength is now built in using a network of carefully positioned ribs. This is much lighter than an engine block where the strength comes from walls with an even thickness. The thickness of body panels also varies between thinner central areas and thicker outside areas where the stresses are concentrated.

Racing car bodies are now shaped in a wind tunnel and made from composite materials developed in the aerospace industry. The most familiar composite material is glass-reinforced plastic (G.R.P.) or fibreglass. GRP has long been used in racing cars, but carbon fibre and Kevlar are now used instead of glass fibres for extra strength, extra chassis rigidity and better protection for the driver in a

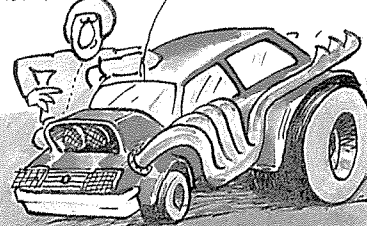


Cosworth-Ford V8 engines are used in many categories of racing. Each cylinder has four valves and the combustion chamber is partly formed in the crowns of the pistons.

Just amazing!

VROOM VROOM!

THE 1989 FORMULA ONE FERRARI HAS ABOUT 650 HORSEPOWER AT THE BACK WHEELS – ABOUT 18 TIMES THE POWER AND 500 TIMES THE PRICE OF A STANDARD FIAT UNO.



Paul Raymond



crash. This is all achieved in a body weighing less than 70kg.

A rigid chassis is important for racing cars because it helps the suspension work efficiently and so the car can corner faster. This brings down the lap time and is one factor that helps a driver to take his place on the winner's rostrum.

Racing car braking systems are also using aerospace technology. The brake disc itself is now made of carbon fibre at a cost of about £2,000 per disc – £8,000 per car. Carbon fibre absorbs much more heat than the conventional cast iron, but at the price of much faster wear on the brake pads. This only becomes critical in long distance racing where pads are often changed at the same time as tyres – perhaps every two hours throughout the race.

With good brakes, a driver can leave his braking to the last minute, and so pass drivers who have to brake before a corner. This out-braking manoeuvre wins many races, especially on narrow circuits where there is not enough space to overtake on corners.

Four wheel drive

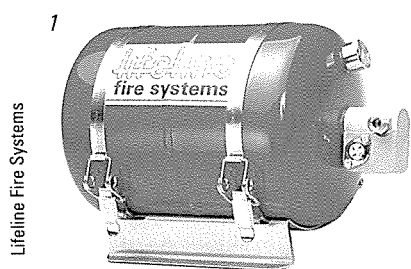
The ever-increasing power produced by the latest racing and rallying cars is useful only if the tyres can transmit the power on to the road without causing the tyre to lose grip and skid. Wider and stickier tyres can help to deal with the power, but the best solution is four wheel drive. Here the engine power is shared between all four wheels, so each axle only has to transmit half the engine power.

MINIMIZING THE RISKS

Fire is a major hazard for racing drivers in the event of a crash. To reduce the risk, all cars are fitted with safety valves in the petrol feed-pipes to prevent leaks if the pipes are accidentally cut. Also petrol tanks are made of rubber to minimize the chance of splitting.

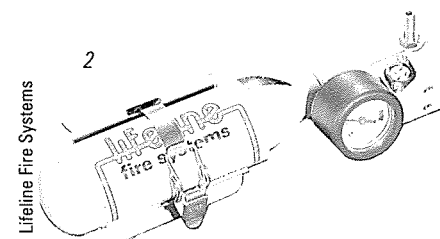
Every car is fitted with an automatic fire extinguisher system. In an impact, an electrical cap flies off a bottle of BCF fire extinguishing fluid. This turns to gas and blankets the engine bay. A separate container of BCF blankets the cockpit.

At the same time a supply of oxygen is fed into the driver's helmet. This replaces the oxygen consumed by the fire and gives a conscious driver precious seconds to free himself from the safety harness and get out of the car. An unconscious driver has to rely on the marshalls who should arrive on the scene within seconds.



Lifetime Fire Systems

1 Fire extinguisher tank containing BCF. 2 Oxygen bottle with gauge. 3 Driver clad in fireproof Nomex fabric, wearing safety helmet.



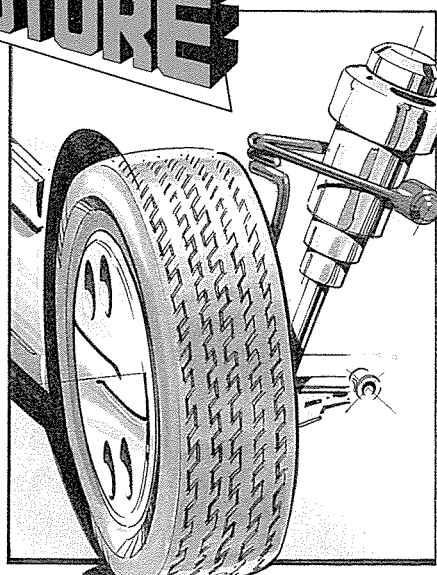
Lifetime Fire Systems



Allsport

INTO THE FUTURE

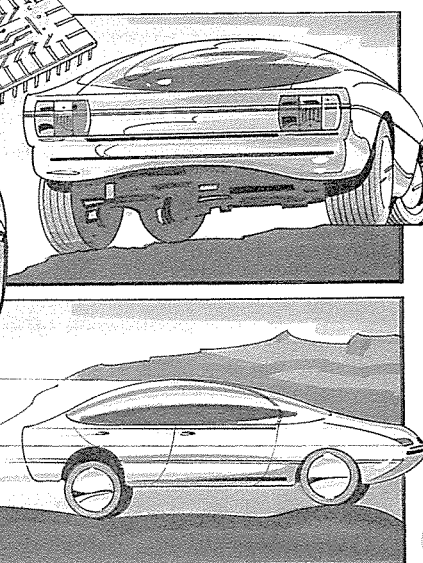
ACTIVE SUSPENSION



▲ The fastest racing cars will be fitted with 'active suspension'. Instead of metal springs, the weight will be supported by quick-acting hydraulic jacks.

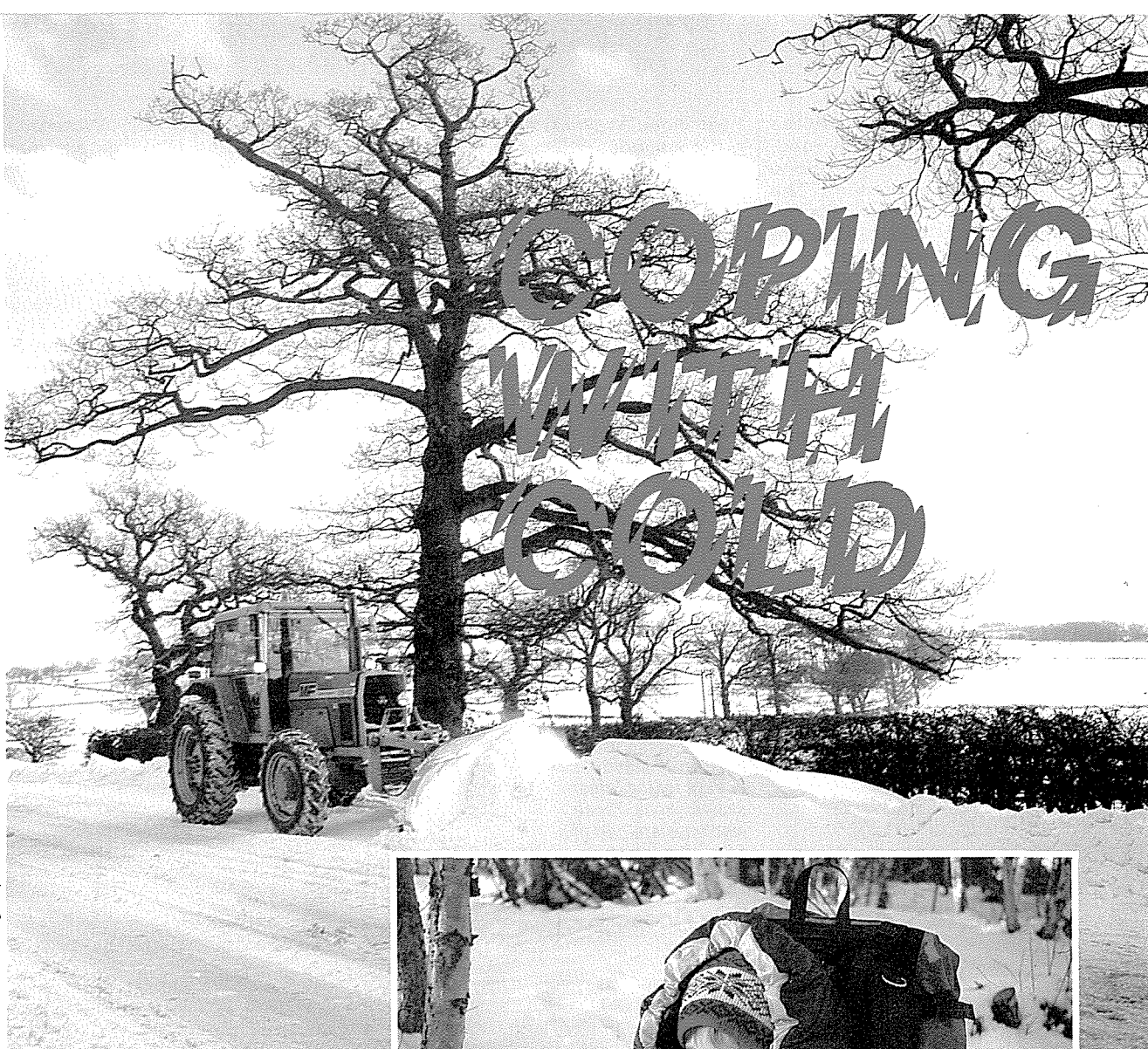


▲ Electronic height sensors using radar will be fitted in front of the wheels to detect bumps and potholes before the car passes over them.



▲ A micro-processor then works out how much each wheel has to be raised or lowered to keep the car on an even keel and so corner as fast as possible.

COPING WITH COLD



Frank Lane Picture Agency

-  WARNING NETWORKS
-  WATERPROOFS
-  SNOW BUSINESS

MACHINES AND MATERIALS come to the rescue when the weather gets too hot, too wet or too cold. A great deal of effort goes into dealing with the effects of cold weather in particular, as snow and ice can severely disrupt both travel and communications.

Keeping wintry roads clear is a sophisticated and well-organized business involving salting trucks, snow ploughs, snow blowers and, in some areas, computer-controlled warning networks that include electronic roadside monitoring stations.

Snow busters

In areas that have more than their fair share of snow, a salt and grit mixture is used to keep the roads clear. Salted water freezes at a considerably lower temperature than salt-free water, so salting snow makes it melt and drain away. If the



Cameron McNeish/Mountain Camera

temperature were to drop dramatically after salting, however, the melted snow would turn into sheet ice. Using grit in conjunction with the salt prevents this from happening.

Gritting machines can be mounted on lorries or towed behind vehicles, and fleets of these are used to deliver a measured dose of salt and grit.

Trucks can also be fitted with snow ploughs for road clearing and farmers are sometimes called on to mount snow ploughs on tractors to deal with snow drifts of up to two metres. Snow blowers

***Prolonged exposure** to wet and cold can cause hypothermia. A waterproof sleeping-bag keeps the body warm and dry. A mix of salt and grit helps to keep roads open (top). As salt melts the snow, grit prevents it from re-freezing.*

with turbocharged diesel engines can be mounted on mechanical diggers to cope with snowdrifts up to five metres deep.

In some weather-monitoring networks there are roadside sensors that can measure air temperature, road temperature, soil temperature,



wind speed and direction, as well as the salinity of water on the road. The sensors are linked by telephone lines to a computer system. The computer system receives information from a central weather centre and has a sophisticated programme of its own to assess the need for salting all, or just certain, key roads that are at risk from ice or snow.

Keeping snug

In wintry weather, clothing made with thick insulating materials is ideal. Perhaps the best of these is down, particularly that of the Eider duck. If the garment is designed properly so that there are no thin patches, then down – worn with several other layers of clothing – can keep out the worst cold, including that found at the north and south poles. Any other fabric or material that traps small pockets of

heat close to the body will make a good insulator against the cold.

Another heat-retaining material is the thin, shiny, metallic, reinforced fabric popularly known as the 'space blanket'. This does not stop air from escaping, but retains radiated heat by reflecting it back.

Modern fabrics are designed to keep rain out and let perspiration out too, cutting down on the 'wet inside' feeling from non-permeable coverings such as rubber and poly-

vinyl chloride (PVC). Waterproof fabrics such as Gore-tex are made up of an outer fabric above a lining material over a membrane that has nearly 10 billion tiny holes, or pores, in every 6.5 sq cm of material. Each pore is about 20,000 times smaller than a raindrop, but 700 times larger than a water vapour molecule produced by perspiration. Thus, water produced within can get out – but rain or melted snow cannot get in.

The armed forces are kitted out to cope with weather extremes. Uniforms, made of Gore-tex, allow for sufficient ventilation to deal with perspiration, but prevent any rain seeping through to the wearer's skin.

Snow blowing machines are used to clear minor roads in outlying areas which have insufficient access for the larger snowploughs. These machines are part of a specialized fleet of equipment.



John Cleare/Mountain Camera



E. Nevill/TTH

HYPOTHERMIA – THE VITAL SIGNS

Long immersion in cold water, wearing wet clothes at high altitudes and general exposure to cold in an unheated or badly heated house for a long time can all induce hypothermia.

When the body temperature starts to drop below the normal 37°C the victim progressively:

- complains of feeling miserably cold
- feels abnormally cold to the touch
- starts to shiver uncontrollably
- stops shivering and begins to experience a lack of muscle co-ordination and slurred speech
- eventually loses consciousness.

When the body temperature drops to 30°C, the hypothalamus – an organ situated below the brain – loses its temperature-regulating ability. As a result, cell activity and breathing rate slow down and the oxygen supply to the brain diminishes; the heart muscles ripple but do not pump blood. If the victim is not hospitalized at this point, he or she will undoubtedly die.

When dealing with a conscious hypothermia victim:

- replace wet

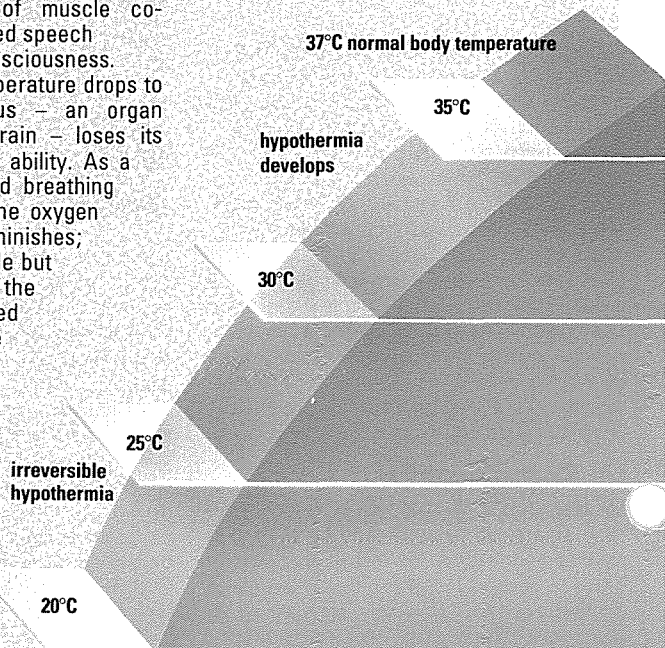
- clothing with dry garments
- wrap them in a blanket, but do not cover their face
- do not rub or massage them
- do not give them alcohol
- never place their hands or arms in direct contact with their body.

Just amazing!

FAT WONDER

A 125 KG ICELANDER SPENT SIX HOURS IN ICY WATER. THEN WALKED FOR THREE HOURS OVER A FROZEN LAVA FIELD WEARING ONLY JEANS, A SHIRT AND A SWEATER. HE WAS SAVED BY THE 14 MM LAYER OF FAT ALL OVER HIS BODY.

Paul Raymond



Janos Marffy

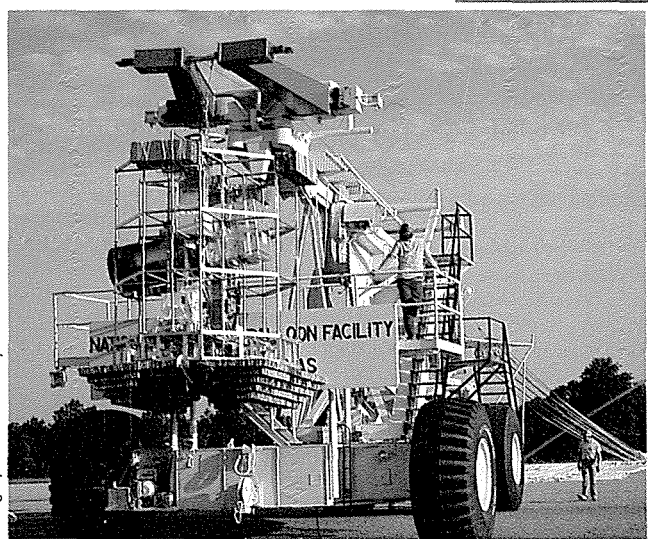
 JET STREAM WINDS

 WEATHER BUOYS

 NUMBER CRUNCHERS

POWERFUL NEW TOOLS available to meteorologists enable them to produce more and more accurate predictions. Reliable forecasts can now be made for 24 hours ahead, and work is underway to refine the long range forecasts that look up to a month ahead.

All this effort is not just to make sure that you choose a sunny day for your picnic. It is a matter of life, death, or large sums of money for all sorts of people. These include not only fishermen and sea captains wondering whether or not to put to



Telegraph Colour Library

sea, but also airline pilots and farmers who want a fine, settled period of weather to sow and harvest their crops. Even ice cream makers vary the number of cornets they make according to the weather forecast.

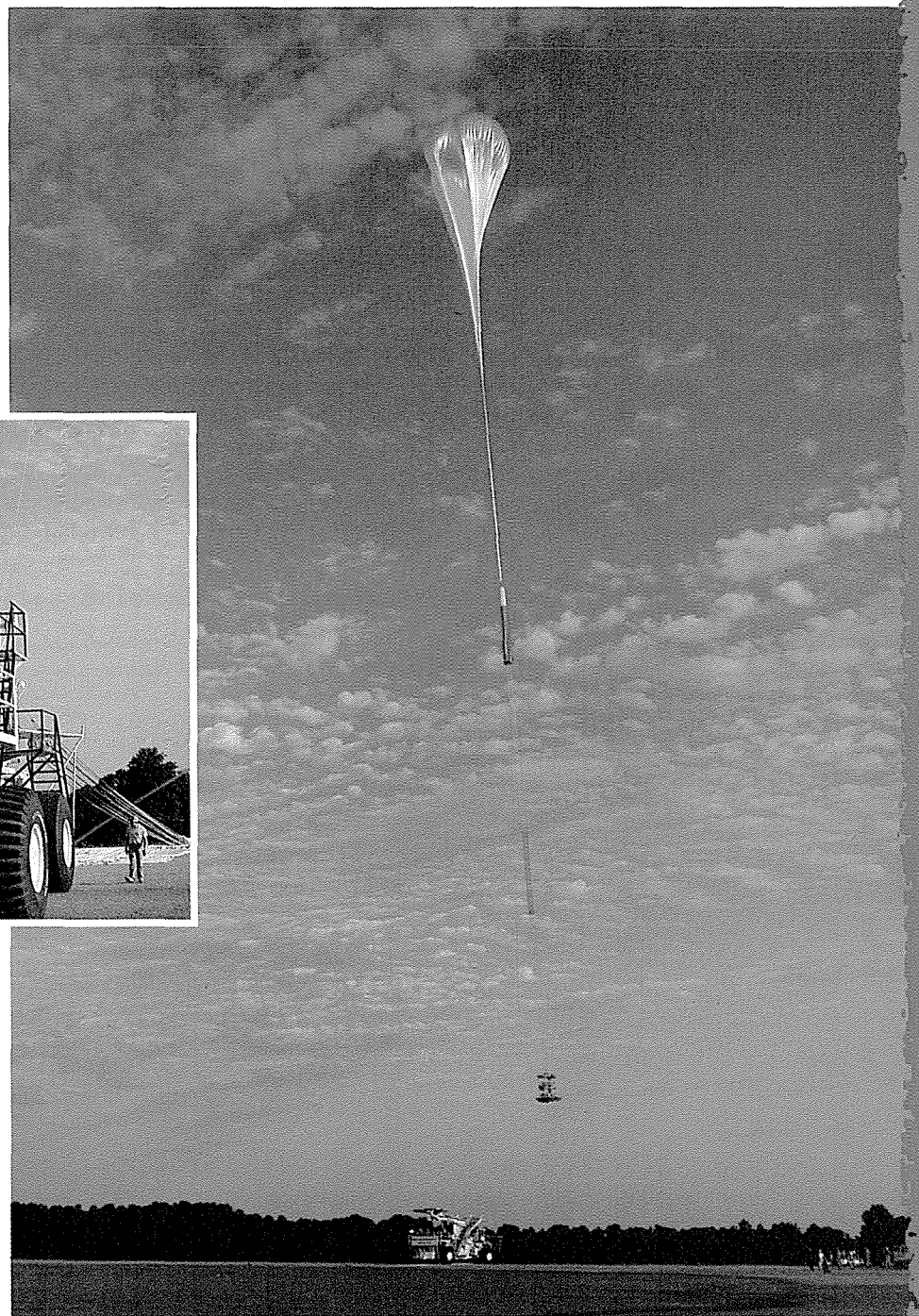
Before meteorologists can make a forecast, they need to have an extremely accurate picture of what the weather is doing over as large an area as possible. So weather observations are collected from:

- ground stations
- stratospheric weather balloons
- a countrywide radar network
- polar-orbiting and geostationary satellites
- oil rigs and automatic buoys
- civilian aircraft and ships
- special weather flights.

Synoptic observations

All levels of the atmosphere must be observed because a shift in the upper atmosphere winds of 2,000 km can trigger a radical change in the weather. That upper atmosphere change might, in turn, be a reaction to a weather event in the opposite hemisphere two or three

FORECASTING



days previously. So weather information must be collected all round the world to give a complete picture.

The accuracy and type of observations made are crucial, as well as the time when they are made. In order to get a snapshot of what is going on at any one instant, observations are made synoptically. This means that they are taken at the same time worldwide, with the main observations coming at 00.00, 06.00, 12.00 and 18.00 Co-

Radiosonde balloons are launched from airfields using a large trailer (inset). The balloon carries instruments and a radio that parachute back to Earth.

ordinated Universal Time (UTC) or, as it is otherwise known, Greenwich Mean Time (GMT). The data are then sent via communications satellite, land line or radio to one or all of the world's meteorological centres.

At a ground station, a trained observer measures wind speed and

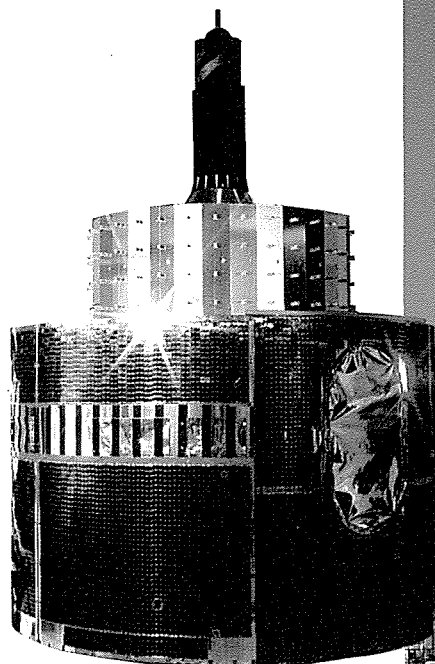




Lumier/Jerrican

Most ground stations have a louvred enclosure that shelters the instruments without cutting them off from the weather phenomena that they measure.

Meteosat geostationary weather satellites (below) are launched on Ariane rockets from Kourou in French Guiana. Each one covers a fifth of the globe, so five are constantly on station to provide worldwide coverage.



ESA

direction, as well as visibility, atmospheric pressure, air temperature and dew point temperature. (See Elements in Action, Planet Earth, pages 29–32 for information on dew point.) The observer also reports cloud types and amounts, and general weather conditions. He or she also measures the amount of rainfall, hours of sunshine and temperature maximums and minimums on a daily basis.

Despite their name, ground stations can also be on water – around the world there are thousands of stations all making identical weather reports. For example, in the British Isles alone, there are about 65 weather stations that report back every hour of the day and night to the British Meteorological Office Headquarters at Bracknell, Berkshire. Another 35 or so weather stations report back every hour during daylight.

Weather ships

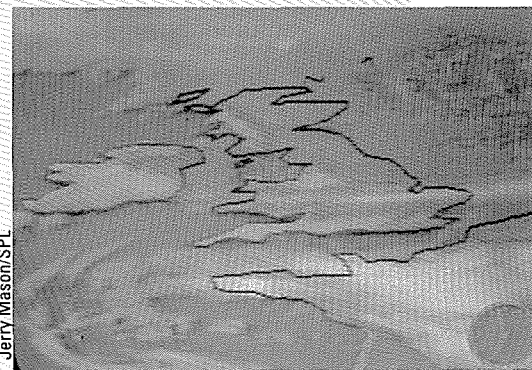
Weather forecasters used to rely on weather ships for mid-ocean observations, which are very important because this is where many weather systems are born. These are now being replaced by automatic buoys. The buoys transmit weather data back to a data collection station on land. There is also a moving network of about 7,000 merchant ships that carry meteorological apparatus and report back. Of these ships, about 2,500 send their reports to Bracknell.



Useful as all the observations taken at surface level are, they must be complemented by measurements of weather conditions higher up in the atmosphere. This is where balloons (called radiosondes) come in. Around the world there is a network of stations where helium- or hydrogen-filled instrument carrying balloons are released every six or 12 hours.

The balloons rise 15 km in the air

TV WEATHER MAPS



Jerry Mason/SPL

Satellite pictures can be used, along with radar observations, to make a picture of the weather systems over a large area. The two forms of data are merged in a computer that presents the results on screen as they happen – ‘in real time’. These pictures are often used to illustrate the weather forecast on TV. They are also used by the TV weathermen themselves to up-date their forecasts as necessary. Satellite pictures of weather systems are very easy to interpret. A knot of clouds means a storm, and a careful look often reveals a cold front.

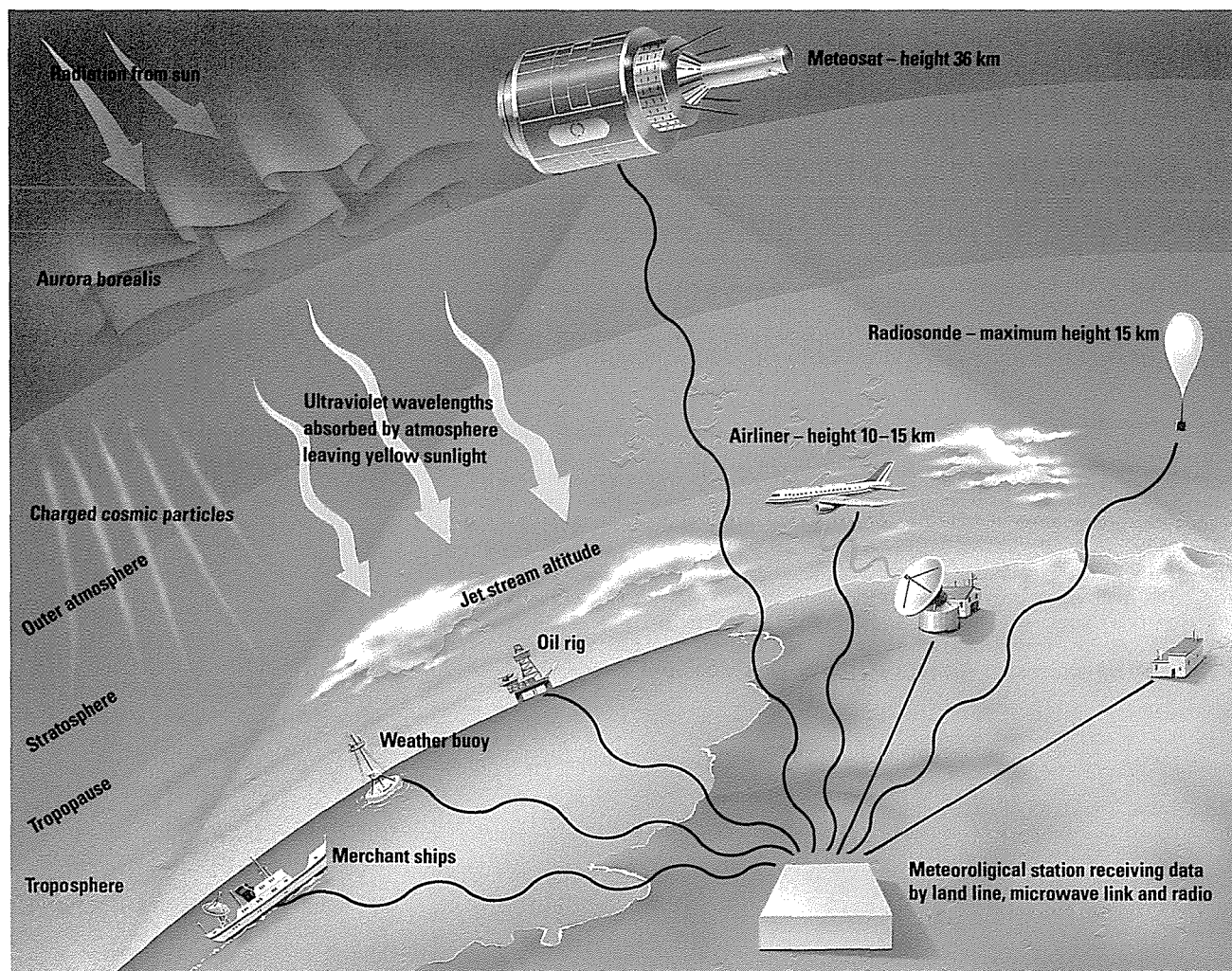
before they burst. The instruments measure pressure, temperature and humidity at frequent intervals during the ascent, and transmit the data to a ground station or satellite, which then relays it to Earth.

The wind speed and direction are determined by radar tracking of the balloon as it climbs. From launch to maximum height takes about an hour. There are not as many balloon-launching stations as the meteorologists would like – they are expensive to maintain – especially in the oceans.

An alternative scheme called the Automated Shipboard Aerological System (ASAP) is already being employed. Merchant ships launch balloons that transmit their data direct to a satellite that relays it to a ground station. The balloon’s movements after launch and, therefore, the wind direction and speed are tracked using a satellite navigation system.

Aircraft

Jet airliners fly at a height of 10–13 km, which is one of the most important levels of the atmosphere.



Chris Lyon



U.S. National Science Foundation

Photovoltaic cell panels, which convert sunlight into energy, are used to power some ground stations. They even work in northern latitudes.

This is where the jet streams blow from west to east at speeds up to 300 km/h. Changes in a jet stream trigger major weather changes. As an example, it was a very fast jet stream that caused the 1987 hurricane-force winds in southern Britain and western France. To observe these changes, many aircraft are now being fitted with automatic instrument packages that col-

lect and report back temperature, wind speed and direction, wind turbulence and the plane's position and height.

The data are transmitted automatically every hour to a weather centre via communications satellites. The system, called Aircraft to Satellite Data Relay (ASDAR), is providing weather forecasters with much valuable information about the upper atmosphere. The system is also able to make readings as a plane climbs or descends, filling out the picture sent back by radio-sounds.

Satellites

Satellites have made a dramatic impact on weather forecasting because they can send back large enough pictures of cloud formations to show complete weather systems. A sequence of pictures taken at different times enables forecasters to see how weather systems are moving and developing.

Currently, two sorts of meteorological satellite are used. Geo-stationary satellites, such as the Meteosat series, cover about a fifth of the world's surface on a permanent basis. Polar orbiting satellites, such as the Tiros series, send back data from narrow strips of land from north pole to south pole.

The troposphere is the scene of most of our weather. Data is collected by satellite, ground stations, buoys, oil rigs and balloons to be analyzed by computer.

Sunshine recorders focus the rays of the Sun on to a strip of paper – the length of the burn indicates the hours of sunshine.



Casella



Satellites carry radiometers to measure electromagnetic radiation. This radiation comprises visible light, infra-red (heat) radiation and microwave radiation. They also use infra-red techniques to make assessments of temperature and humidity at various levels in the atmosphere.

Satellites are particularly important to weather forecasters because they provide information from areas where balloon coverage is poor. The information gathered by satellite is relayed back to ground receiving stations for analysis.

Accurate forecasts

Some countries maintain a network of weather radar stations. These give an accurate – and instantaneous – picture of how belts of rain (associated with warm and cold fronts) are moving across country. With this information, forecasters can compile accurate short-range forecasts. Such forecasts have a very practical purpose. They can,

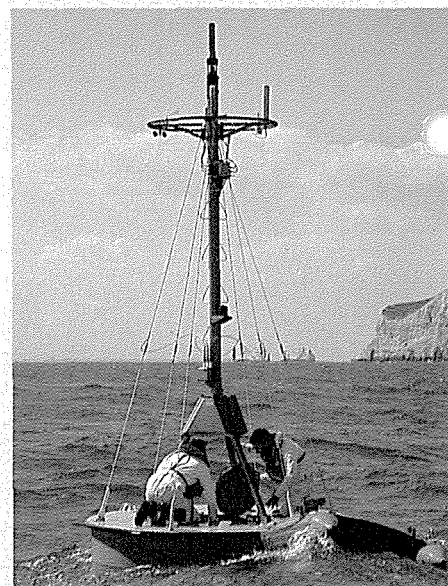
the synoptic readings taken at 00.00 UTC and 12.00 UTC to determine the current situation. The model is then used to forecast the weather situation as it will be minutes, hours and days ahead using equations developed by expert meteorologists.

Computer charts

One mathematical model running on the COSMOS computing system works out the weather for all the points on an imaginary grid, with points spaced about 150 km apart at ground level. It also works out the weather for 15 heights in the atmosphere above each grid point using radiosonde and aircraft data.

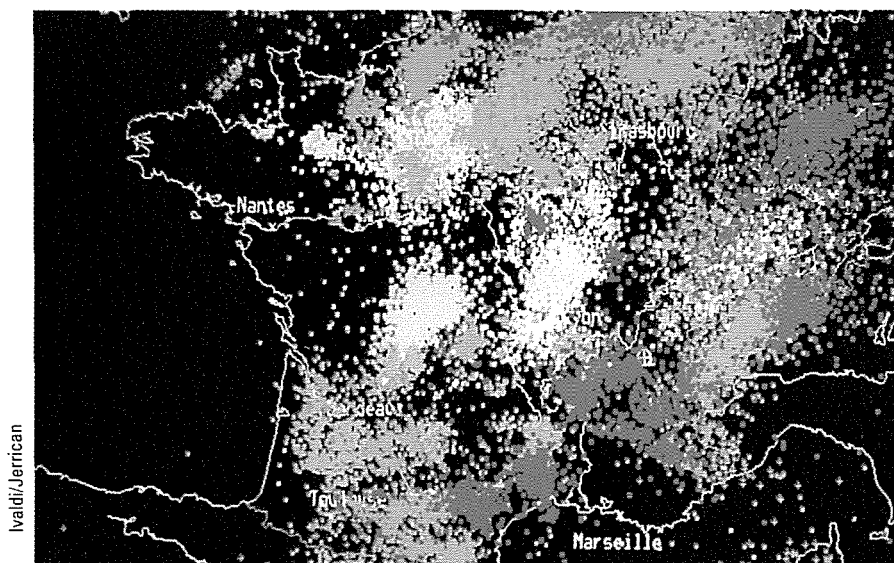
Meteorologists add any other information they think appropriate from other sources such as satellite observations and aircraft readings. The information is then presented on charts drawn by the computer. These charts show the atmospheric pressure at different levels of the atmosphere, and are worked out up

ELECTRONIC BUOYS



Weather buoys were developed for studying both weather and sea conditions in the North Sea during the exploration stage of North Sea oil. The basic buoy – a steel drum about 2 metres across and 1 metre deep – is divided into waterproof compartments containing the micro-computer, the radio transmitter and the batteries.

As well as standard weather observations, weather buoys can be used to measure wave height and currents within the sea itself. The top of the drum carries a mast about 5 metres high, which supports the main meteorological sensors. The sensors for sea conditions are attached to the mooring cable. Weather buoys can transmit data back to a computerized shore station for up to one year before the batteries and transmitters need servicing. Buoys are normally anchored in shallow water, close to the coast, but deep water versions are also used.



Ivaldi/Jerrican

Satellite data relayed back to Earth is recorded on magnetic tape. Computers process the data and draw up maps showing features that meteorologists wish to study. The dots on this map represent lightning strikes and give a picture of low-altitude electrical activity.

for example, influence whether or not a local council will salt the roads to prevent ice forming.

A worldwide network of meteorological communications centres are linked by very fast telecommunications circuits so they can exchange these vast amounts of coded data quickly. There is so much data to process that it can only be done by the most powerful computers.

Weather forecasting systems are based on computer programs that are mathematical 'models' of the way the weather works. These use

to six days ahead.

At the end of the computer run, charts and forecasts are examined by a human meteorologist who interprets the information in the light of experience. He or she also takes local geographical features such as mountain ranges and low lying land into account because these can make the difference between low cloud and rain.

COSMOS, the computer-based forecasting system, processes 3½ million numbers every time it draws a map of the atmosphere. As each number involves several calculations, the computing capacity required is phenomenal.



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SKY LINERS



AIR TRAFFIC

LANDING SYSTEMS

SPACE PLANES

THE WORLD'S BUSIEST airports each handle over 1,000 aircraft take-offs and landings per day at the height of the holiday season. This can mean that over 100,000 passengers have to be guided safely, quickly and without annoyance through the airport during the course of a day.

An outbound aircraft comes under the control tower's surveillance even before it has started its engines. Permission to start engines is requested by radio from the Ground Movement Planner, who can observe the movements of all aircraft and vehicles at the airport from the Visual Control Room in the tower. He is assisted by ground movement radar, which displays a screen image so detailed that he

can even see abandoned rubbish lying around the airfield.

Permission to take off comes from a different authority – Airfield Control, also located in the Visual Control Room. Once in the air, the plane is guided towards the airway, or air lane, along which it will fly. As the plane leaves the terminal control area, control is passed on yet again to the neighbouring region's Air Traffic Control.

One way traffic

The airways are like motorways in the sky, 16 km wide and extending from about 1.5 km to 7.5 km high. Streams of planes fly along each airway in one direction only. Aircraft at the same height are separated by at least 9 km horizontally. If they are separated by less than this horizontally, they must be at least 300 metres apart vertically.

At peak times, a plane wanting to land may have to wait in the stack – a series of circling flight paths near a radio beacon some kilometres from the airfield. The levels of the stack are spaced at least 305 metres apart. The aircraft descends



Heathrow Visions

The Visual Control Room (inset above) has ground movement radar (large screen) and a distance-from-touchdown indicator (small screen) to aid safe landings at Heathrow (top).

in the stack until it can eventually come in to land. When it is lined up to land, about 10 km from touchdown, control is passed to the Air Arrivals Controller in the Visual Control Room. During its descent, the aircraft is kept on course by the instrument landing system (ILS), which uses two radio beams. The localizer beam extends along the centre line of the runway – to a distance of 40 km in the case of London Heathrow. The glideslope beam helps the pilot bring the plane down at the correct angle. When the weather is clear, he can also see carefully angled lights beside the runway that change appearance if his angle of approach is incorrect.

Radar displays

The skies are scanned by two main types of radar. Primary radar sends out ultra-high-frequency radio pulses that bounce off aircraft. The reflected radar signal is picked up by the radar antenna. The direction of this echo and its delay in returning reveal the position of the aircraft, which is shown as a 'blip' on the radar's display screen.

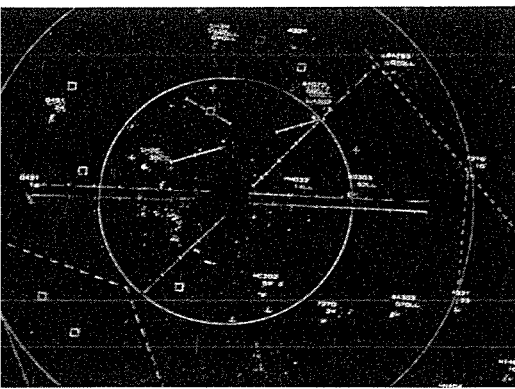
Secondary radar also sweeps the sky with a radio beam that triggers a device on the aircraft called a transponder. This instantly sends out a radio pulse with coded in-

Good communications with the air traffic controllers are essential for safety in busy airspace around London's Heathrow. Direct radio communications allow contact with aircraft, emergency services and airport vehicles. Controllers can speak to aircraft and vehicles on different radio frequencies at the same time.

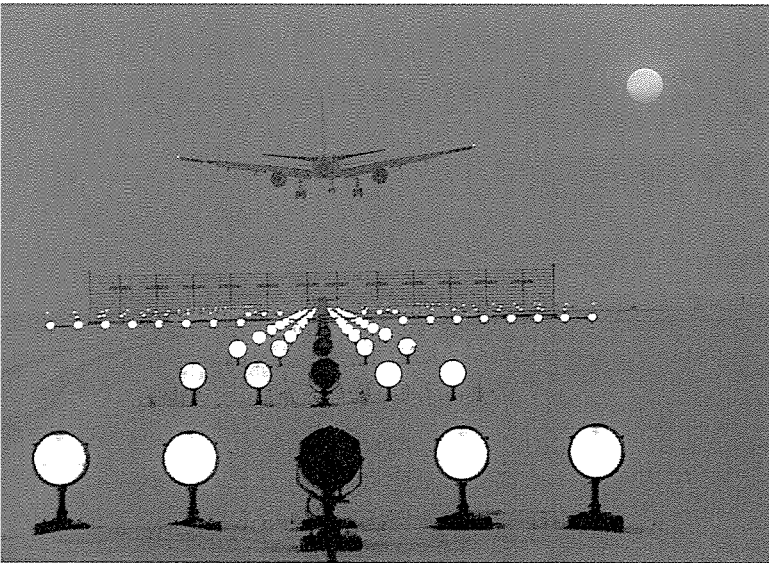


Heathrow Visions Picture Library

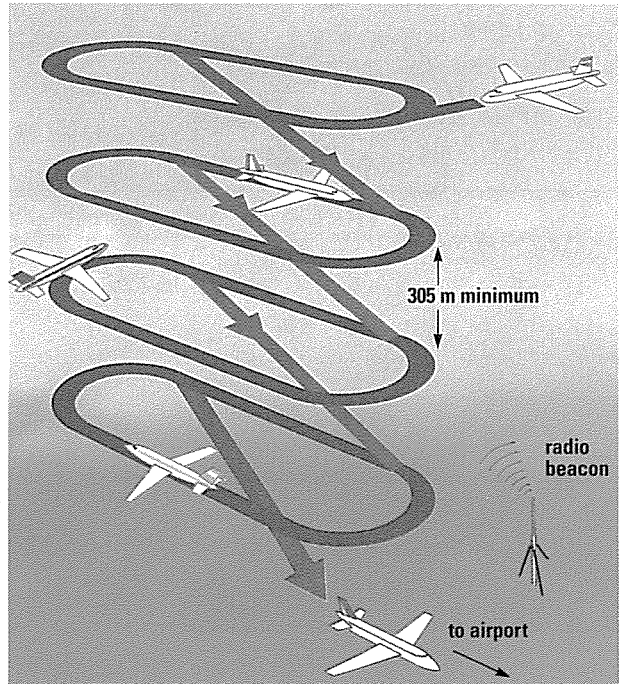




The radar display used by air traffic controllers shows aircraft positions and movements. Planes transmit identification signals; a computer converts these into call signs that are displayed on screen to identify each blip.



Tony Stone Photo Library, London



Mark Franklin

Lights and radio beams help the pilot approach the runway from the correct direction and at the right angle as he brings the aircraft in to land at major airports.

Aircraft wait in a stack in an area marked by a radio beacon. When a runway becomes free, the bottom plane lands and the rest move down the stack.

formation. The radar aerial picks up this signal, and the blip on the display is labelled with the aircraft's call sign. If there is some kind of emergency on board, such as a hijack, the pilot can press a button so that a warning message to that effect is also displayed on the Air Traffic Control radar.

Passenger flow

Imagine the problem of dealing with the passengers from ten jumbo jets that arrive at an air terminal in a half-hour period. That's not an unusual load — yet it can mean that about 4,000 people have to be reunited with their baggage and processed smoothly through customs formalities and immigration checks.

There must also be room at the airport for the friends and relatives who've come to greet passengers or see them off. New airport handling facilities, like those operating at New York's Kennedy International Airport, aim at processing an amazing 6,000 passengers an hour.

Airport design

Another problem faced by all airports is how to spare passengers long walks to or from the plane. A parked jumbo jet takes up a bay about 90 metres wide. If a dozen of

these planes were parked side by side, passengers would have to walk over one kilometre to get to the furthest one.

Moving walkways

Airports are carefully designed to reduce this problem. In many cases, aircraft berths are arranged along piers that stick out like spokes from a hub that contains a departure lounge. Even so, moving walkways are standard in many airports now. Other 'people movers' include slow, constantly moving 'trains' that travellers step on to and off again. Another solution is to park aircraft out on the apron, well away from buildings, and take the passengers out to them in comfortable mobile lounges.

The movement of baggage is more highly automated. At the check-in counter, the baggage is weighed and tagged so that it will find its way on to the same plane as its owners, and will be reunited with them at their destination. It is carried on conveyor belts to a baggage loading point where it is packed into containers that can be loaded straight on to the aircraft.

Electronic scanning

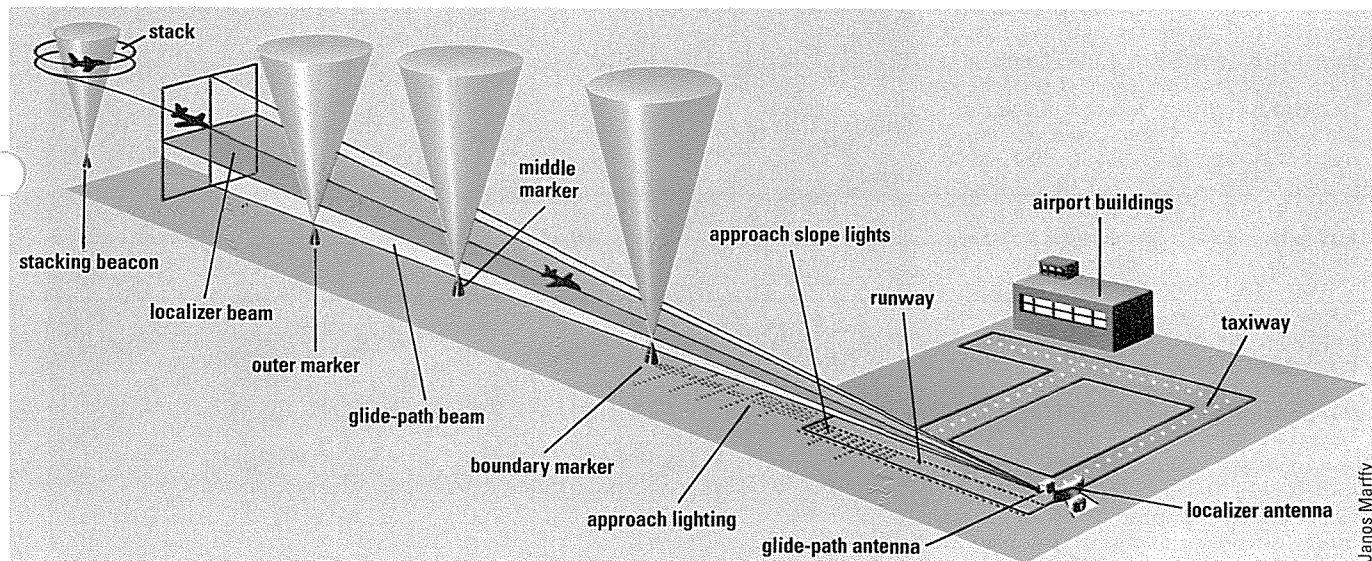
In advanced modern systems, baggage tags are electronically scanned and the bags are automatically sorted and despatched to the right destination. In some airports, the bags are moved by robot tractors, which are called DCVs (destination-coded vehicles).



Heathrow Visions Picture Library

London's Heathrow is the world's busiest international airport, with over 300,000 landings or take-offs each year, involving over 30 million passengers and some 600,000 tonnes of goods.





Radio beams from two antennae guide planes leaving the stack on to the correct approach path to the runway. Marker beams along the approach path tell the pilot how far the plane is from the runway.

A topless Boeing 737 lands at Hawaii, its cracked and corroded roof having been ripped off during the flight. Only one person died, but 56 passengers were injured in this freak accident.

In the future the problems will be intensified by the efforts of airports to increase their plane-handling capacity. Improved methods of air traffic control will permit them to bring aircraft in safely with smaller separations, and even to use parallel or converging runways simultaneously.

This will mean a corresponding speed-up in passenger handling. Passengers won't have to wait so long for bags if plane cabins are redesigned to allow them to take more in with them as hand baggage; in addition machine-readable documents will speed up checks.



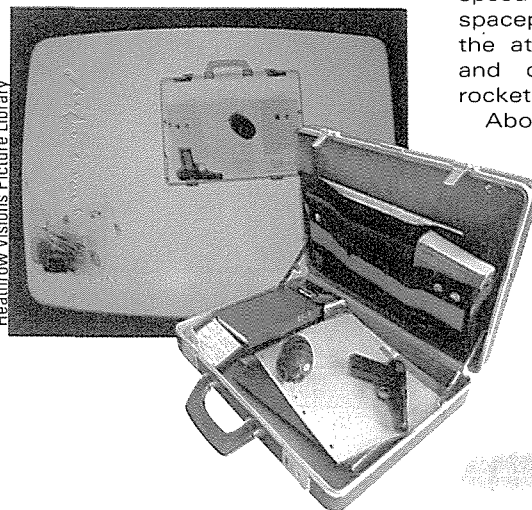
Passengers infuriated by long delays in overcrowded departure lounges often accuse airport authorities of treating them like cattle. Actually, cattle, cats and koalas are considerably better treated at some airports. Frankfurt, for example, is very proud of its animal station — a special facility for animals in transit. It can cope with animals and birds of all sizes. There are 12 boxes for large animals and adjacent sand-filled runs in which they can exercise. Eight large quarantine cells are available for isolating animals until they can be certified free of disease by a veterinary surgeon.

Their waste is heat-treated to disinfect it, and the air is filtered before it is discharged to the atmosphere. There are also eight dog kennels with insulated floors to make sure that the occupants don't catch chills. A vet is always on hand and various kinds of animal food are prepared in a well-equipped kitchen.

Hypersonic airliners

Work is already well under way on the hypersonic airliner of the future. When it arrives it will have a distinct resemblance to a space rocket. The technology that will enable it to cruise at more than three times the speed of sound will also be used in spaceplanes that can climb through the atmosphere using jet engines and continue into space using rockets.

About 80 per cent of the weight

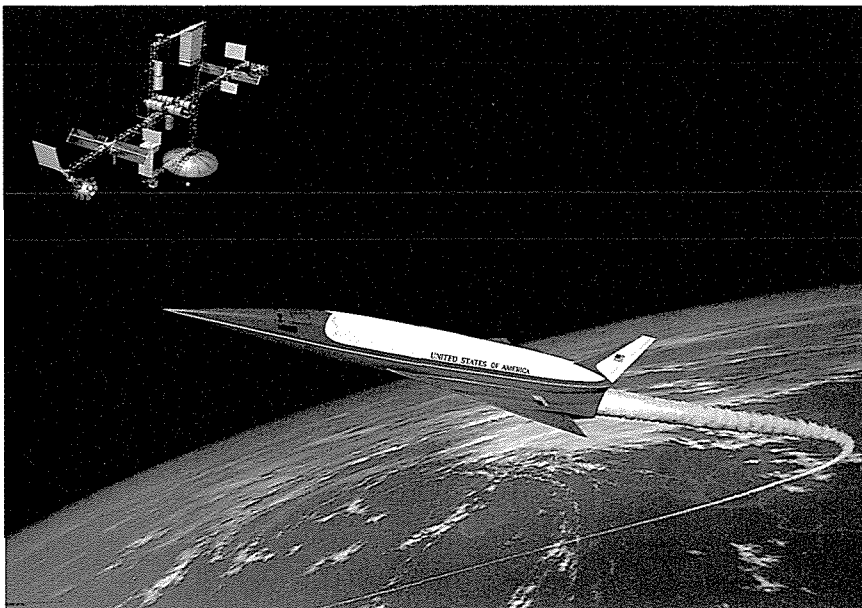


The danger of terrorism on international flights is an increasing menace, so it is essential to check baggage with an x-ray machine. Guns, grenades and other metallic objects are easily spotted on the screen when the baggage passes through the machine on a conveyor belt.



of a Space Shuttle's propellants consists of liquid oxygen, which is needed to burn the liquid hydrogen fuel. A spaceplane will be able to use the oxygen in the thin air at high altitudes, so it will need to carry much less oxygen. This technique could cut the costs of launching a satellite in low Earth orbit – say, 300 km high – to a fifth of what they are today.

The USA has dubbed its proposed hypersonic airliner the Orient Express, since Japan will be an important destination for American travellers. It is pressing ahead with a research aircraft called NASP, the National Aerospace Plane, an early version of which will fly in the mid-1990s. In one proposed design, NASP will have three engines – two quite different sorts of jet and a rocket. A turbojet will be used for take-off and for flight up to speeds



NASA

NASA's hypersonic aircraft will take off from ordinary airport runways to reach the other side of the world within two hours. It will also fly directly into Earth orbit to take men or materials to space stations.

Helicopters fly low to avoid interfering with the much faster conventional aircraft at higher altitudes. Over large towns, helicopters usually have to fly along rivers or over parkland to keep clear of buildings.

of Mach 2–3. A turbojet has a fast-spinning turbine that compresses the intake air to make fuel burn well.

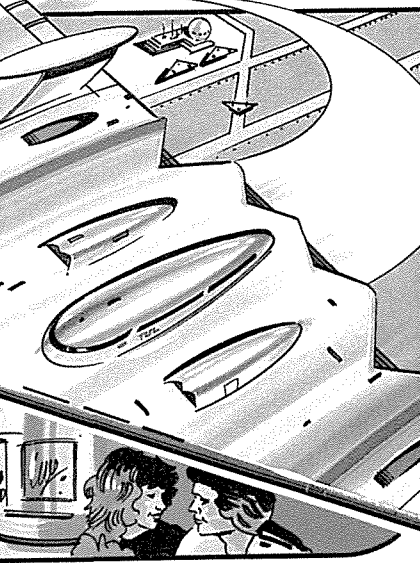
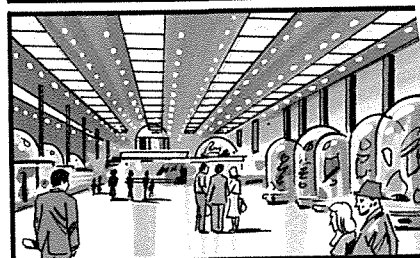
Scramjet

At higher speeds, the intake air would be diverted into the other engine. This will be a hydrogen-burning scramjet – a supersonic combustion ramjet. A ramjet has no moving parts. It relies on the aircraft's high forward speed to ram air into it and compress it.

The French AGV (Avion à Grande Vitesse) is planned for about the year 2010. It is designed to fly 150 passengers from Paris to Tokyo or Los Angeles in three hours. The German Sanger II vehicle will be able to carry 250 passengers on a 15,000 km journey.

INTO THE FUTURE

THE FLYING LOUNGE



▲ Long-distance air passengers enter a lounge, put their bulky luggage into lockers and relax over a meal, watch a video or go shopping.

▲ The lounge, built into a huge flying wing aircraft, takes off. Smooth acceleration and efficient stabilizers make it unnecessary to be strapped in.

▲ On very short trips, such as London to Paris, most passengers stand, holding on to ceiling straps.

HIGH-TECH ARTICS



DISC BRAKES

GLASS FIBRE SPRINGS

ENERGY ABSORBERS

WHEN A DRIVER CLIMBS INTO the cab of his giant articulated truck, he enters a home from home – and that's just what he needs, whether he's crossing a continent or spending a week away from home picking up and dropping loads all over the country.

These sleeper cabs are equipped with one or two bunks behind the seats, a wardrobe, cooking facilities and an independent heater for use at night. The heaters are fed with

diesel from the main tank but do not burn the fuel; instead, the fuel is turned into heat with a catalyst, for safety reasons.

The driver's work load is very tiring because juggernaut trucks have up to 18 gears, which have to be matched to engine speed, the gradient of the road and the load on board. To reduce the amount of work the driver has to do and achieve more accurate use of the gears, an increasing number of trucks are fitted with pneumatically-assisted and computer-controlled gearboxes. The driver selects a gear by moving a small gearstick. He starts and stops using the clutch in the normal way, but for all other gear changes, the gears and clutch are operated automatically using air-power. In addition, the computer signals to the driver when to change gear.

Hard ride

Truck suspensions tend to give the driver a very uncomfortable ride, so many trucks are fitted with seats that have a separate springing system. In extreme cases where heavy duty trucks are used cross-country for oil exploration and construction

Articulated trucks (or 'artics') of the year 2000 will be highly aerodynamic: the cab and the trailer wheels will be blended into the bodywork.

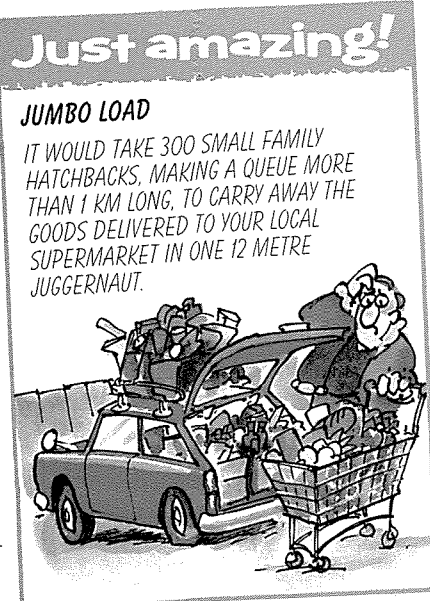
work, drivers could not keep control without a suspension seat.

Better still, more trucks will be fitted with cabs that are separate from the rest of the vehicle. Hydraulic cushions can be fitted between cab and chassis to damp out shocks transmitted from the road.

Better brakes

Disc brakes are now being fitted to more and more trucks. These stop a loaded lorry much more quickly than drum brakes and cost less to maintain. What is more, disc brakes are self-adjusting so they always work at maximum efficiency.

In mountainous countries, where a driver often needs to keep the



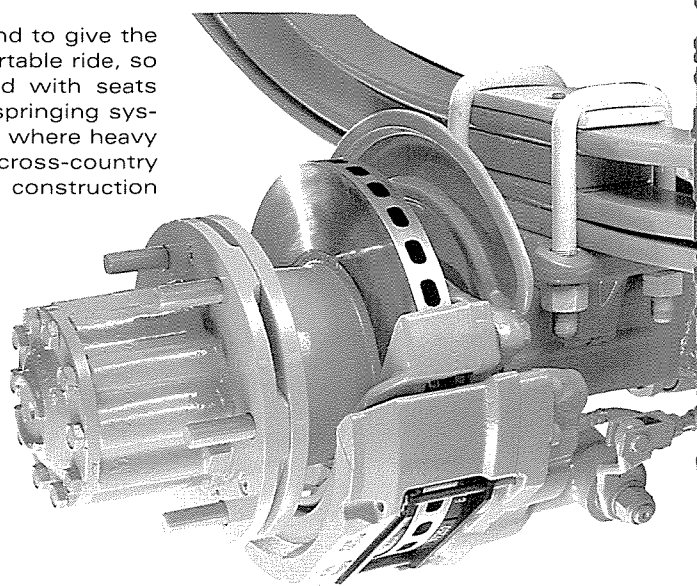
JUMBO LOAD

IT WOULD TAKE 300 SMALL FAMILY HATCHBACKS, MAKING A QUEUE MORE THAN 1 KM LONG, TO CARRY AWAY THE GOODS DELIVERED TO YOUR LOCAL SUPERMARKET IN ONE 12 METRE JUGGERNAUT.

Disc brakes will be fitted to the trucks of the future. All brakes heat up rapidly when used, but air circulates freely round a disc keeping it cool and, therefore, more efficient.

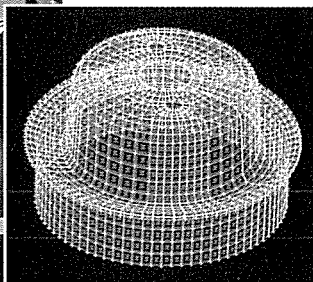
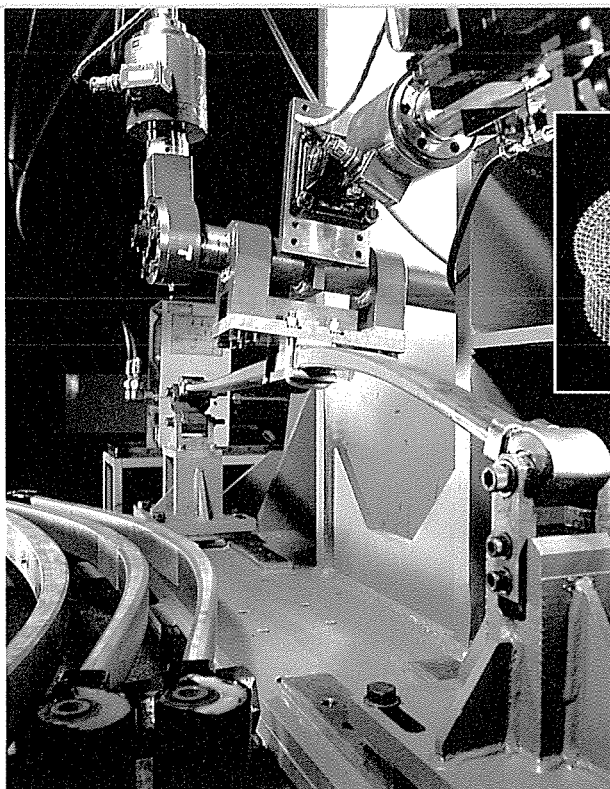
Maintenance is easy because there is nothing covering the mechanism.

Iveco Ford (Truck) Ltd



Renault Véhicules Industriels





Test rigs are designed to reproduce the sort of stresses that a component will be subjected to while it is in daily use. These can be visualized on a video screen (above), but there is no substitute for a real life situation.

GKN plc

Cummins Engine Co Ltd

the year 2000, truck maintenance will be so expensive that the extra cost of a retarder will be a worthwhile investment for long distance operators.

Juggernaut trucks will look smoother and more stylish in AD 2000. They will certainly be more aerodynamic and will weigh much less when empty. The main trends are that:

- Fewer trucks will be needed, but each one will carry more freight.
- Less steel and more lightweight metals, plastics and composites will go into their construction, so they will be lighter when empty. This means that they will be able to carry more cargo within the maximum weight of 40 tonnes.
- They will be quieter. The current aim is a noise level of 80 decibels – about the level of 1989 cars.
- Instructions to drivers for deliveries and pick-ups, navigational information, distance covered, fuel used and expenses incurred will automatically be transmitted to and from head office via satellite.

Modern turbo-charged diesel engines and simple aerodynamic improvements like flush headlamps have already reduced the fuel consumption of a juggernaut from about ten times to about six times that of a small diesel car. The modern juggernaut is very economical to operate and is likely to become even cheaper in the future when ceramic pistons will enable engines to run much hotter.

As more and more freight traffic is transferred to the road from the railways, roads will start to break up unless this is taken into account when trucks are designed. Thus rubber and glass fibre suspensions will become standard as they can be tailored to cope with the enormous difference in weight between an empty and a loaded juggernaut.

CONTROL CRUNCH



Transport & Road Research Laboratory

Trucks are involved in fewer accidents per vehicle-km than other vehicles. But when an accident happens, trucks are lethal because they are so much heavier than anything else on the road.

Trucks are already fitted with guards at the rear, to stop smaller vehicles disappearing underneath the juggernaut. They also have side guards, which reduce the chance of a cyclist or motor cyclist rolling beneath the truck in an accident. These barriers are fixed at present, but in the future they will be fitted with energy-absorbing struts (arrowed above) so other road-users have more chance of survival.

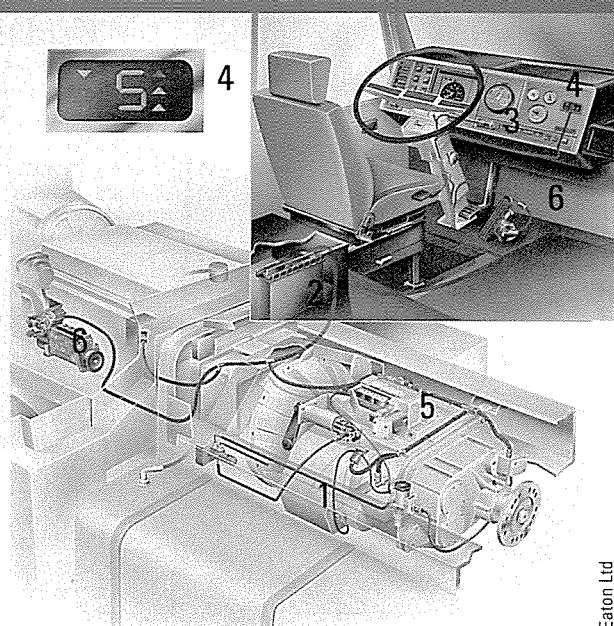
Another safety problem is the curtain of spray thrown up by heavy trucks on wet roads. Special materials, such as 'artificial grass', are fitted inside the wheel-arches to suppress the spray but this is only partly effective. Shaping the truck body to control the airflow combined with full enclosure by side skirts will give better results by the year 2000.

brakes on for 10 or 15 km, the main braking system is often aided by an exhaust brake. In this system, the exhaust is partly blocked when a control on the dashboard is operated. When going downhill, the engine is left in gear and the blocked exhaust multiplies the engine braking effect.

At the moment, some passenger coaches are fitted with electric brakes or 'retarders'. The braking effect is produced by electromagnets mounted on the end of the gearbox, so electric brakes can be used for long distances without overheating. The brakes are regulated from the dashboard and the amount of braking can be controlled accurately, unlike an exhaust brake, which is either on or off. Electric brakes also save a lot of wear and tear on the main braking system. By

SEMI-AUTOMATIC TRUCK TRANSMISSION

Electrical wires replace the direct mechanical controls on a semi-automatic gearbox. This is the first step towards 'drive-by-wire' and the fully electronic truck where the steering and diesel fuel pump are also computer-controlled. 1 12-speed gearbox 2 Control computer using inputs from speedometer, throttle and gearbox 3 Gear selector close to steering wheel 4 Dashboard display 5 Air-powered gear changers taking signals from control computer (2). 6 Electrical throttle control.



Eaton Ltd



Q STEEL SKELETONS

Q DIZZYING HEIGHTS

Q SWAY FACTOR

THE SKYSCRAPER FOREST
that is New York's Manhattan would be impossible to re-create in London. This is because Manhattan Island is one huge chunk of granite, whereas London is built on a

Spectrum Colour Library

SKY HIGH

A grid of skyscrapers in Toronto, Canada, creates wind tunnels. At 553 metres, the CN Tower (right) – the world's tallest freestanding structure – can sway 2 metres.

bed of clay and is scarcely capable of sustaining a building of more than 60 storeys.

Weight is a prime problem in the construction of high buildings. The stress on the lower sections of a very tall building is only slightly less than the stress on the foundations. For this reason, the top section of a skyscraper must be made of lighter materials. Most multi-storey buildings have a frame which is usually made from steel girders that become thinner and lighter towards the top.

Swaying in wind

One of the other great strains a tall structure has to take is the bending moment – the leverage force exerted on the base when winds strike the top. As a rule, the taller a building, the beefier its base.

Winds buffeting the top of a 100-storey building are four times as strong as those hitting a 50 storey building. A hurricane can exert 4,000 tonnes of pressure against the side of a very tall skyscraper!

Wind vibration of a building can have drastic consequences, particularly the frequent, intermittent gusts that arise when winds are forced down narrow street networks between skyscrapers. Like any other structure, a building has what is called a 'natural frequency'. This is a vibrating frequency at which the structure will begin to vibrate with



greater motion than the force which caused it to start moving. The vibrations increase in intensity until they shake the structure to pieces.

To counteract wind-induced motion, huge weights can be mounted on rails near the top of a skyscraper. As the building moves, the weights start to move too. Because they are still moving in the original direction when the building sways back, they act as a counterbalance – killing the swing.

Winds also pose a hazard at street level. Buffeting gusts can sweep pedestrians off their feet. This is a regrettable (but unavoidable) consequence of a skyscraper city. However, if winds get into a tall building at ground level they can travel upwards via the lift shaft and can do great damage. On many tall buildings, the lift shafts are staggered – you have to change elevators half way up to get to the top – to avoid this ever happening.

Safety

How do engineers design skyscrapers so they are strong enough to withstand the various stresses they have to endure? A great number of calculations can now be made from computer simulations. The strengths of materials and different structures made from them can be programmed into a computer, as can forces, such as gravity and wind pressure. The building is then designed on the screen and the computer predicts whether it will stand up and in what conditions it will remain standing.

Any building must always have an element of redundancy – that is,

A temple of steel to modern finance, the building of the headquarters of the Hong Kong and Shanghai Banking Corporation. Like a lobster, it wears its 'skeleton' on the outside, proudly showing off its main structural features. High rise living and low cost sampans (below) are a feature of crowded Hong Kong.



George Wimpey PLC



Tony Stone Photo Library, London

Trade Centre built in the city in 1973.

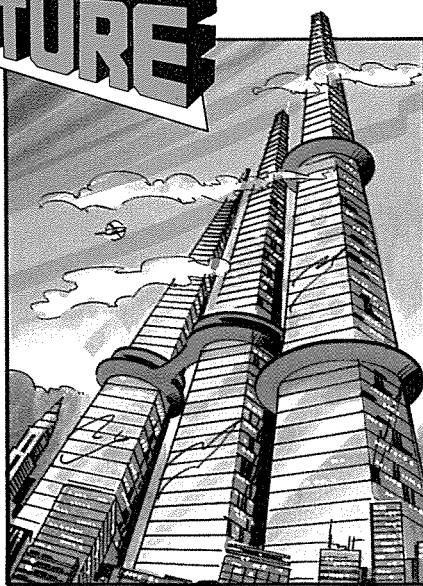
Better understanding of how buildings react to the strongest gales, plus the development of high strength steels and concretes, have allowed architects to design structures twice as high as existing ones.

To discover peculiar problems that may occur with particular designs, scale models are built and tested in wind tunnels. When the Chicago architect, Harry Weese, placed a 1.4 metre model of his design for a 210-storey building in a wind tunnel, the tip of the tower began to oscillate violently. In a full-scale building, this would have

more structural strength than it needs in order to withstand the greatest forces it will ever have to face. Early skyscrapers had a great deal more redundancy than the buildings of today. For instance, the Empire State Building, erected in New York in 1931 to a height of 381 metres, has a greater weight of steel per metre than the much taller 412-metre, twin-towered World

INTO THE FUTURE

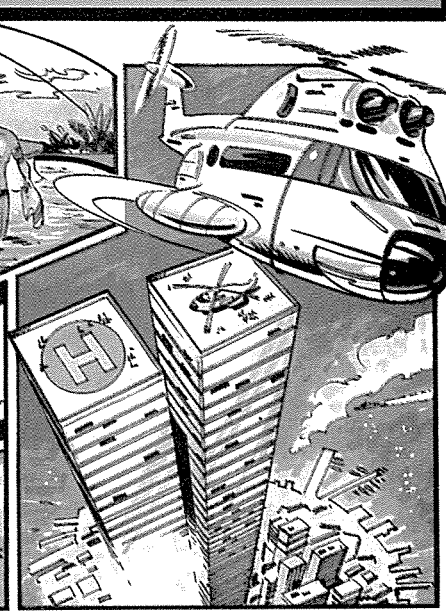
LIFE IN THE SKY



▲ With buildings planned that will reach 1.6 km into the sky, it will never be necessary for a resident to venture into the danger of the street.



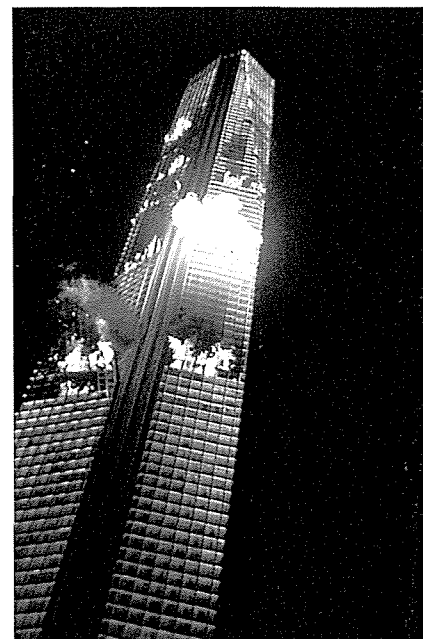
▲ These skyscrapers will not only provide a home and workplace for their inhabitants, they will also house medical services and the shops they would need.



▲ They will have entertainment facilities, such as a cinema, swimming pool and even a concert hall. There will also be a heli-pad on the top of each building.

'intelligent' because they control their own environments and operations without requiring people to switch systems on and off.

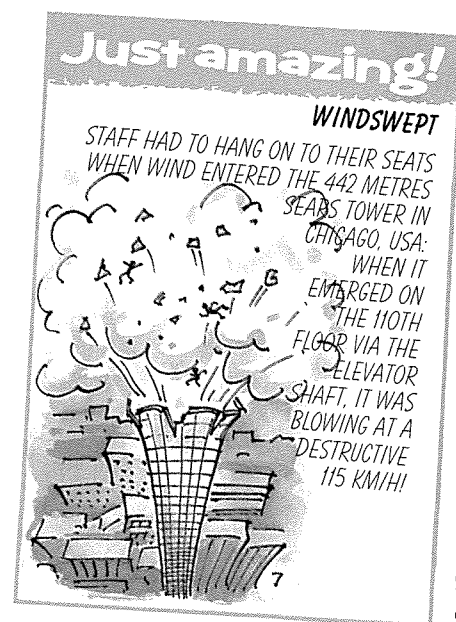
Buildings of more than 25 storeys are erected almost exclusively for offices or other commercial purposes. This makes computer control of utilities an easier task, as people tend to arrive at work and leave at roughly the same times. It is, therefore, possible to have a 24-hour cycle for, say, a heating



Warner Bros/Kobal Collection

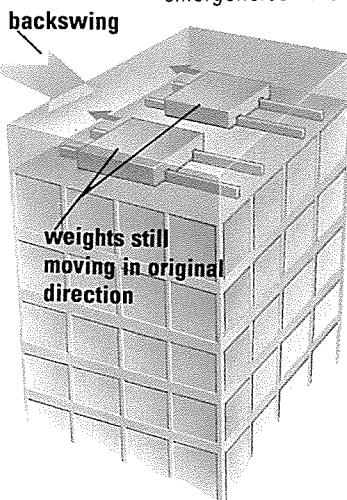
system, so in winter it is on during office hours and off throughout the night.

All these elaborate control systems depend on electrical power. If this fails for any reason, the building shuts down. There must, therefore, be an emergency generator system to carry out essential functions in the event of a power cut – to work the lifts so that people can be evacuated, for instance.



Paul Raymond

Chris Lyon



Large weights on rollers at the top of a skyscraper counteract sway: they move with the building and continue in the same direction even as the building swings back, so acting as a counterbalance.

human activation. The sprinkler systems start automatically once smoke or heat alarms are set off. The alarms may also close off the area in which the fire starts by locking fire doors. This confines the blaze and prevents it spreading to the rest of the building.

Computer control

Computers linked to sensors and timers can also control the lighting, heating and security systems of a building. Such buildings are called



Richard Bryant/Arcaid

been a round trip of more than 20 metres every minute. Only a test pilot could keep his lunch down in such conditions.

Towering infernos

Another great risk in skyscrapers is fire. There is no means of escape from tall buildings and the structures become deadly, towering infernos. Two such disasters occurred in São Paulo, Brazil, in the 1970s.

It is also essential that a tall building has the means to extinguish any fire that starts inside it. This is achieved by placing giant water tanks at the very top to supply water sprinkler systems in the ceilings of every floor. Lift doors must also close automatically, because lift shafts are a prime means of spreading fires.

The fire-fighting system has to work instantly, so it cannot rely on

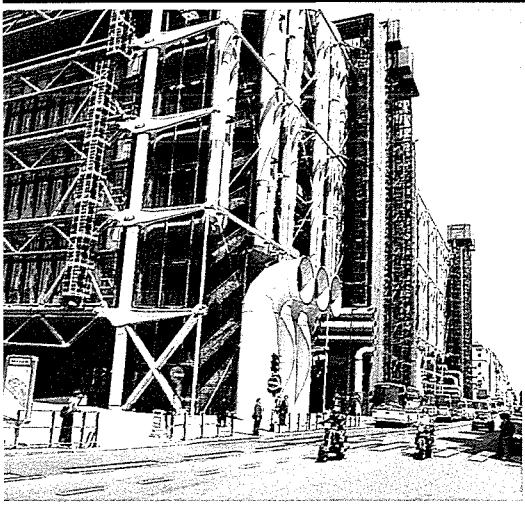
SMASH HIT

Many windows fell out of the 60-storey John Hancock Tower in Boston, USA, in 1974 because of the 'sway factor'. If a building of that height (or higher) sways by more than a few centimetres at the top, the window frames stretch on the away swing, loosening the glass; on the back swing the reverse happens – and the glass is crushed.



Omri Eytan/Architectural Association





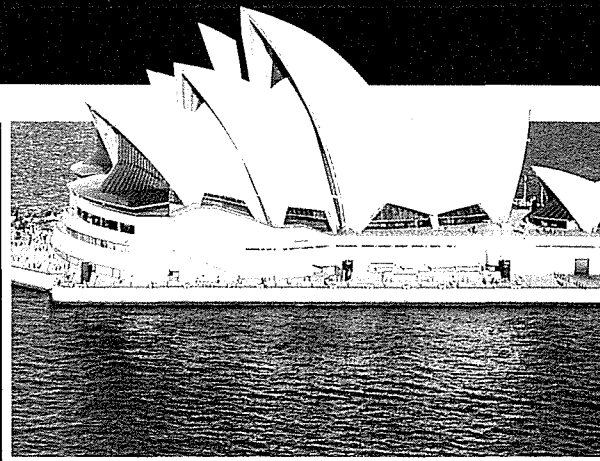
'Inside' is a fair description of the Pompidou Centre, Paris. Its supporting structure, stairs and lifts are all on the outside.

Sears Tower, Chicago, is the world's largest private office building. The 110-storey tower has lifts that get to the top in about one minute.



Spectrum Colour Library

The Opera House, Sydney, was opened in 1973, nearly 15 years after construction began, at a cost of more than £50 million. The design, by Jørn Utzon, was chosen from over 20 competition entries.

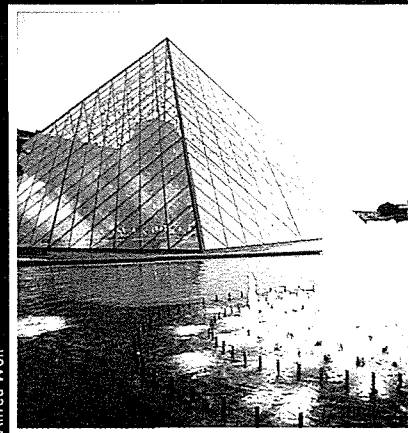


Spectrum Colour Library



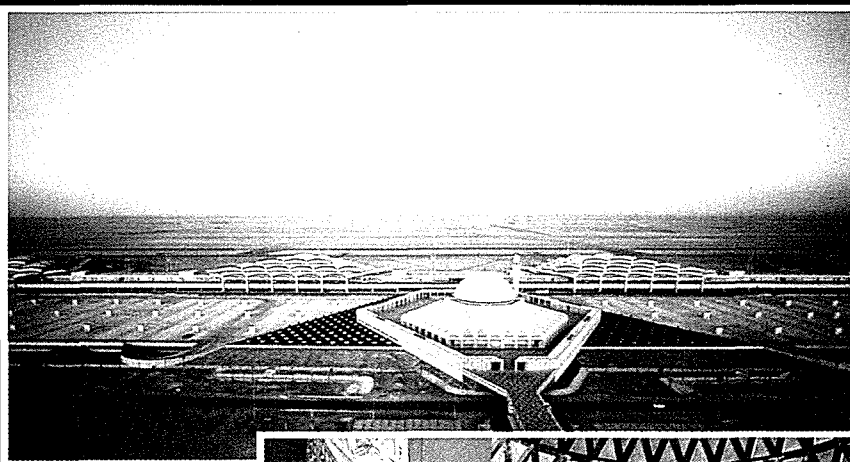
The Portland Building, Oregon, was a protest against plain office blocks. Decorative strips of mirror glass extend up the front of the building, but the tiny, bare windows of the offices make them look like cell blocks.

Alfred Wolf



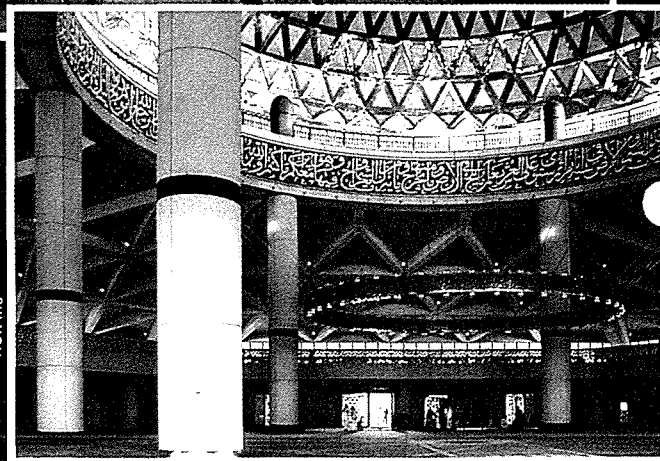
Spectrum Colour Library

A glass pyramid marks the entrance to new galleries beneath the Louvre museum, Paris. Many dislike having such a modern structure in front of the old museum. Other people enjoy seeing the contrast between the old and the new structures.



HOK Inc

King Abdul Aziz International Airport, Riyadh, Saudi Arabia, has two international and two domestic terminals, (ornate interior, right), a Royal Terminal, a Mosque for 5,000 worshippers and a large car park that can accommodate up to 11,000 vehicles.



HOK Inc

MEGA MACHINES

BEEFY BULLDOZERS
STEEL SHUTTERING
LAYING FOUNDATIONS

AS BUILDINGS GET BIGGER and bigger, so they need deeper and deeper foundations. As they get taller and taller and taller, the cranes used during construction have to be higher than ever.

On sites that have never been built on, giant bulldozers with caterpillar tracks are used to push the top soil to one side so that few plants and tree roots will be able to grow under the building and disturb the foundations. The fertile top soil is loaded into tipper trucks and transported to areas such as worked-out quarries where it can be used to rebuild the land surface. Finally the bulldozers level the site.

It is quite easy to build in cities such as Chicago and New York where solid rock lies only a few feet below the surface. But in cities such as Paris with soft clay under the surface, very tall buildings would simply sink into the ground.

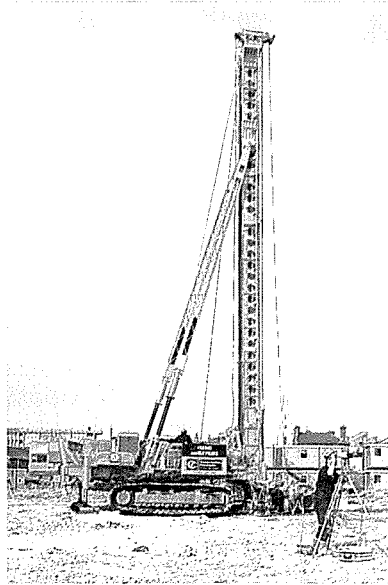
To stop this happening, the first job on many building sites is to test the soil structure using machines, shaped like giant corkscrews, that bore deep into the earth. When these tests have been completed, the site engineers start to drive large tubes into the earth. These tubes, called piles, are driven deep into the earth until they reach the firmer compressed subsoil, sometimes more than 25 metres down. Piles are usually made from concrete and/or steel, so the machines that drive them into the ground have to be very powerful.

Pile driving

Sometimes a top layer of rock or firm ground is supported by softer ground underneath and the piles have to be driven deeper and deeper until they touch bottom.

A pile driver is a very heavy hammer, sometimes driven by a built-in diesel engine. This type of pile driver is hoisted up by crane and sits on top of the pile where it jumps up and down, powered by the diesel engine, driving the pile into the ground.

For deeper work, contractors send for specialists who use gravity-powered machines. These are mounted on caterpillar tracks so that they can work in the deep mud that often covers building sites in the early stages.



Cementation Piling & Foundations

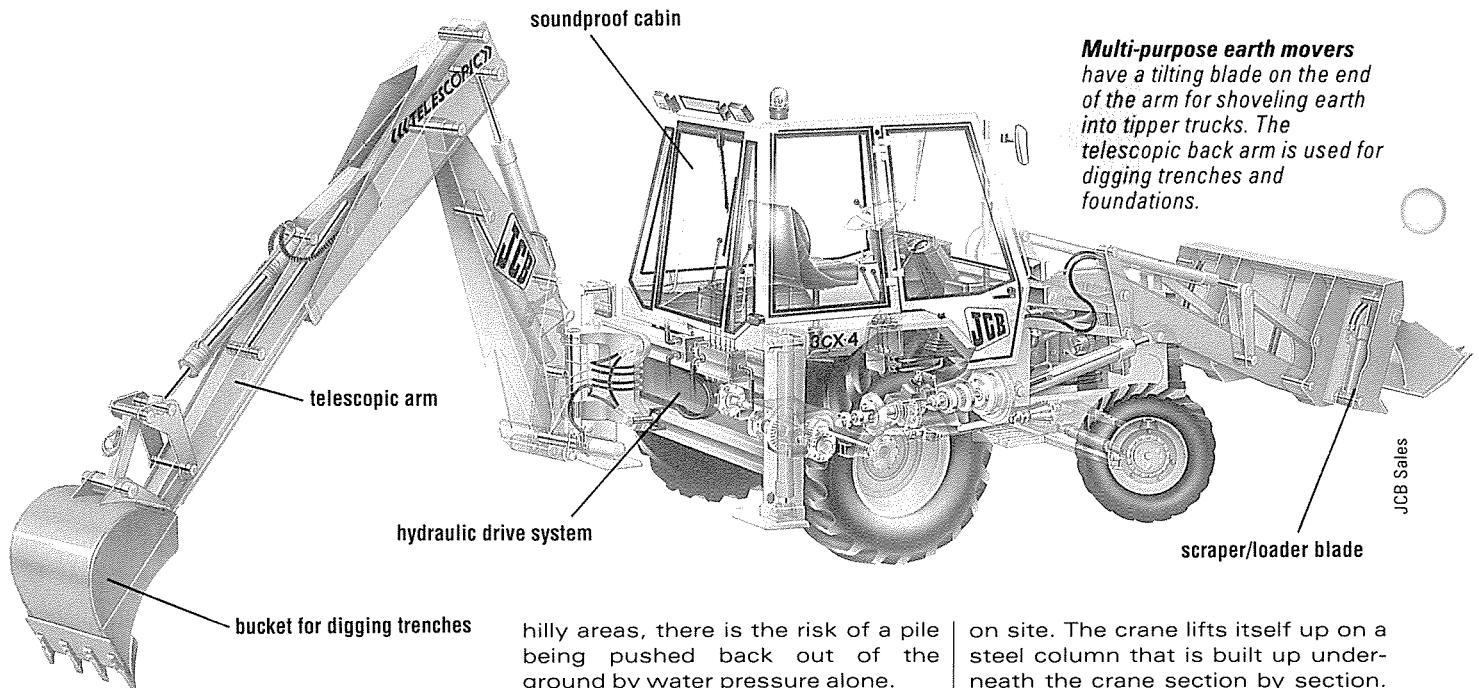
Gravity-driven pile drivers are usually fitted to bulldozers with caterpillar tracks so they can move easily around sites. The tower acts as the guide rail for a large weight which is winched up to the top of the tower, then dropped on to the pile. The impact hammers the pile into the ground.

Each pile is positioned by a surveyor using a theodolite.

Construction sites are crammed with machinery 1 Tower crane, inside lift shaft. 2 Steel reinforcing rods welded together to form core of concrete pillar. 3 Steel shuttering for concrete walls ready for lifting into place with crane. 4 Temporary safety rails to prevent falls. 5 Lift with steel safety cage for site workers. 6 Cement hopper.

Property Enterprise Trusts





Multi-purpose earth movers have a tilting blade on the end of the arm for shoveling earth into tipper trucks. The telescopic back arm is used for digging trenches and foundations.

JCB Sales

In cities where high-rise buildings are close together, the vibration caused by pile driving can damage the surrounding buildings and drains. The noise is also a problem with people trying to work and live nearby. A less disruptive way of making deep foundations is to drill through the soil with giant drills or augers, which are much quieter and vibration free. If the soil is sandy, high pressure water jets can be used to wash out deep holes that are then filled with concrete. These work in the same way as piles.

Flooded foundations

On some building sites, rain water can cause flooding of the foundations. In these conditions, diesel-powered pumps are kept on stand-by twenty four hours a day to clear the water as soon as it collects. If the natural level of water in the ground is very high, particularly in

hilly areas, there is the risk of a pile being pushed back out of the ground by water pressure alone.

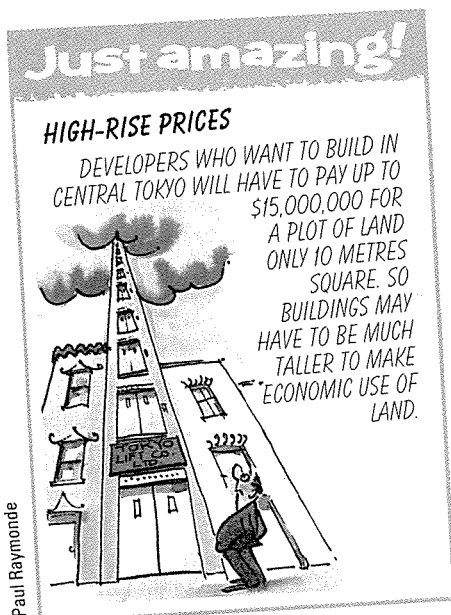
With the use of reinforced concrete and steel girders, high-rise construction has become relatively quick. Steel girders are lifted into position by crane – and it does not necessarily matter whether the crane driver can see what he is doing. He is directed by a man on the ground who communicates through a two-way radio.

Most sites have at least one mobile telescopic crane, mounted on a lorry, that is capable of lifting 16 tonnes up to a height of 120 metres. These machines could lift an elephant up to the top of London's Canary Wharf Tower.

Most big construction sites also have at least one crane assembled

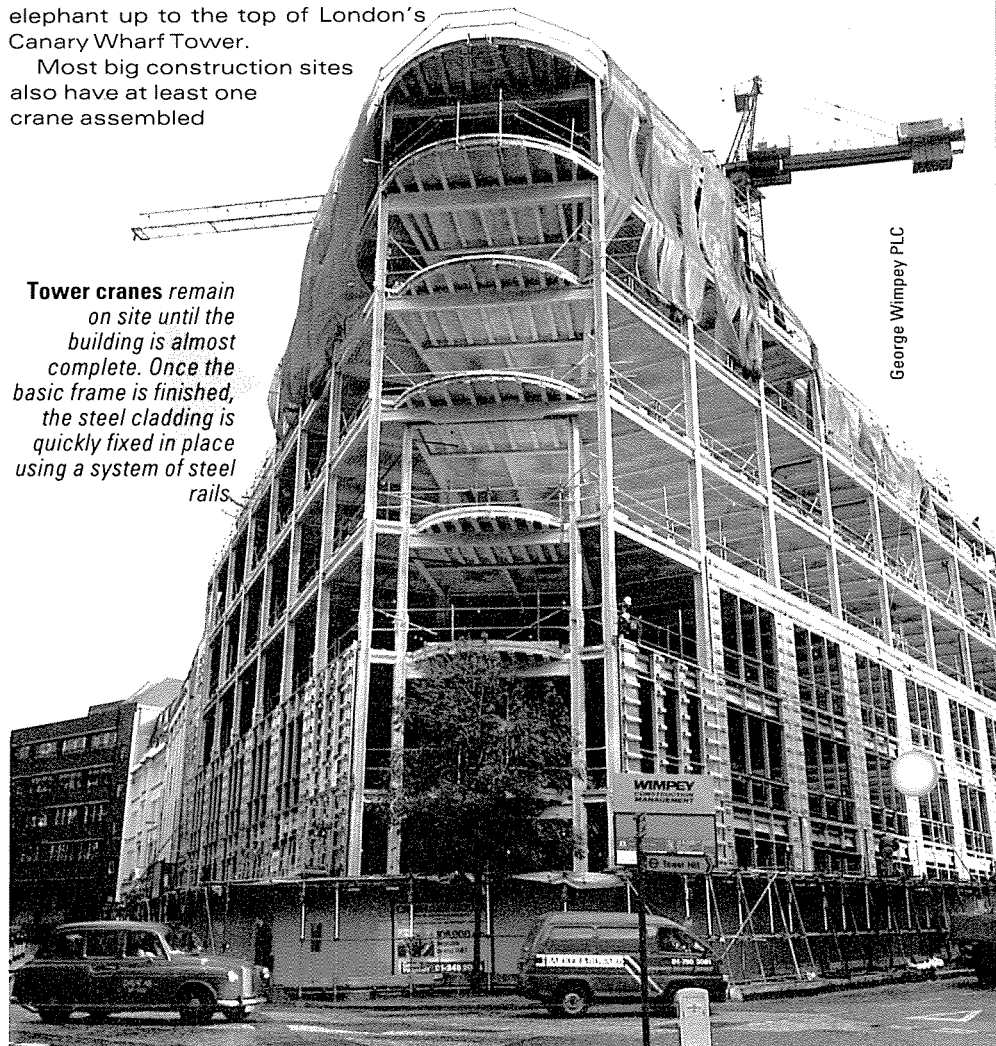
on site. The crane lifts itself up on a steel column that is built up underneath the crane section by section. The building is then constructed around the crane, which is eventually taken to pieces and removed through what will become the lift shaft when the building has been completed.

Concrete pillars, walls and floors are cast in moveable steel or wooden moulds known as shuttering. Concrete is pumped to the top floors in large diameter flexible hoses. A powerful diaphragm pump forces the wet concrete through the hoses and up into the building.



Paul Raymond

Tower cranes remain on site until the building is almost complete. Once the basic frame is finished, the steel cladding is quickly fixed in place using a system of steel rails.

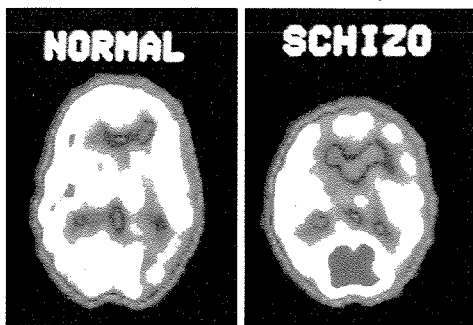


George Wimpey PLC



Crowned with a futuristic helmet, a patient heads for a PET (Positron Emission Tomography) scan. PET scans show how different parts of the brain work, using safe chemical tracers introduced into the body.

US National Institute of Health/SPL



Colour-coded images of normal and schizoid brain PET scans show the differences in the metabolism of a glucose tracer in the brain.

IMBALANCES

SYNAPSES

NATURAL DRUGS

NEUROTRANSMITTERS

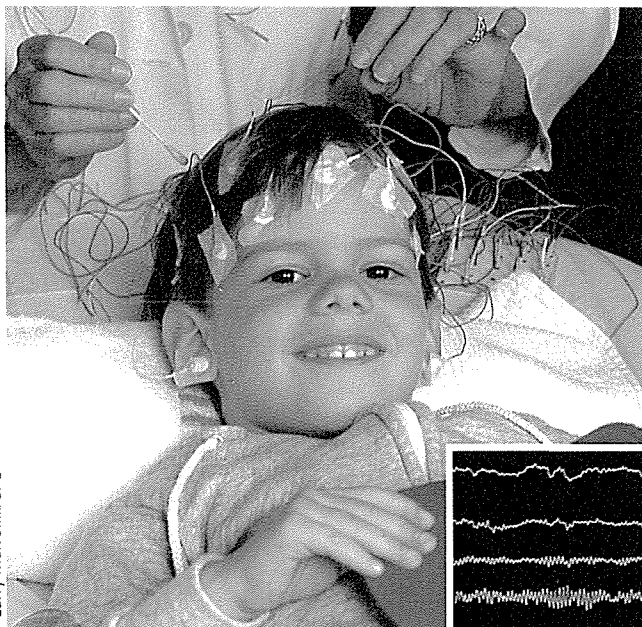
MUCH THAT WE TAKE FOR granted about ourselves – the way we feel, think, react, our very personalities – may well be the result of a delicate balance of chemicals, such as neurotransmitters, in our nervous system. These are transferred at the synapse – the meeting point of two nerve cells, or neurons.

Each neuron is a fluid-filled cell with a semi-permeable membrane. Within the fluid are electrically-charged particles (or ions) of sodium, chloride and potassium. These ions move in and out of the cell through the membrane. The movement of these positively and negatively charged ions changes the electric potential (or voltage) of the membrane, which can then create an electrical impulse.

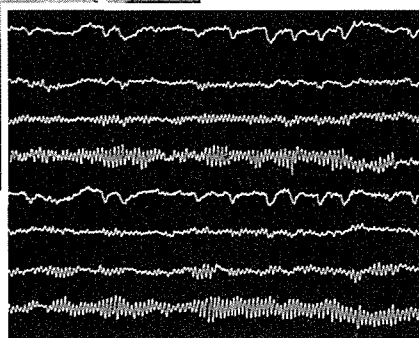
At its end, each axon (the conducting part of a neuron) divides into thousands of nerve fibres that each end in a knob – the synaptic

Roger Ressmeyer/Colorific!





Electrodes will record the electrical activity of the brain in an EEG (electroencephalogram), which will print out as waves (inset below).



SPL

knob. The site where these knobs meet other neurons is known as a synapse.

Within each synaptic knob are vesicles, or sacs, that contain chemical substances known as neurotransmitters. There are possibly as many as 100 neurotransmitters.

Neurotransmitters are either excitatory or inhibitory. Excitatory neurotransmitters let in more positively charged ions through the neuron membrane than they let out: this makes the potential of the membrane more positive. Inhibitory neurotransmitters let in more negatively charged ions, making the potential more negative. Accordingly, an impulse is either fired or suppressed in the nerve.

The electrical impulse, caused by the movement of the ions, draws the vesicles to the edge of the synaptic knob. Here, the vesicles burst open, spilling out thousands

of molecules of neurotransmitters into the synaptic cleft – a microscopic space between the synaptic knob and the membrane of the receiving neuron.

The neurotransmitters from the pre-synaptic cells (the cells where the electrical impulse originated) now move on to the post-synaptic cell – the cell that receives the neurotransmitters; these then pass on the electrical impulse. When the neurotransmitters arrive at the post-synaptic cell, they spark off another electrical impulse that travels along the receiving nerve.

Until recently, only a small, select group of neurotransmitters were known, such as acetylcholine, nor-

epinephrine, serotonin, dopamine, histamine, glutamate and gamma-aminobutyric acid (GABA) – the major inhibitory transmitter substance in the nervous system.

The discovery of many more transmitter substances, commonly grouped together under the heading neuropeptides, has expanded this list considerably. Besides being capable of selectively relaying messages between groups of cells, some of the neuropeptides can evoke quite complex responses. As an example, minute amounts of one neuropeptide, thyrotrophin-releasing hormone (TRH), can induce euphoria and could be used as an anti-depressant.

The various neuropeptides known as endorphins and enkephalins have pain-killing effects similar to morphine. They do this, it seems, by inhibiting neurons from relaying a message that a stimulus should be registered as pain.

Blood-brain barrier

Scientists using dyes to stain animal tissues for examination discovered that there was some sort of barrier in the brain that let through only certain substances from blood. Intravenous injections of dyes would stain all organs except the brain.

Blood capillaries in the brain appear to have a different structure to those elsewhere, so that only water, carbon dioxide and oxygen

ENDORPHINS – THE BODY'S OWN TRANQUILLIZERS

Does rigorous exercise produce its own rewards? Many regular exercisers maintain that they experience a feeling of well-being and elation, particularly during prolonged physical activity. While this may to some extent be due to feelings of self control and a sense of achievement, exercise may also be responsible for an increase in the level of neurotransmitters, such as endorphins and norepinephrine.

The body, under the influence of intense physical stress (such as exercise or childbirth) can produce its own tranquillizers – the endorphins – within the nervous system and elsewhere. They seem to have a pain-killing effect similar to aspirin.

But endorphins also have a part to play in pleasurable sensations and may be the key to understanding the physical origins of pleasure and pain. It seems that a repeated stimulus – as in exercising – will release endorphins, which appear as a reward to the person. This may be why runners love running – both short and long distances.

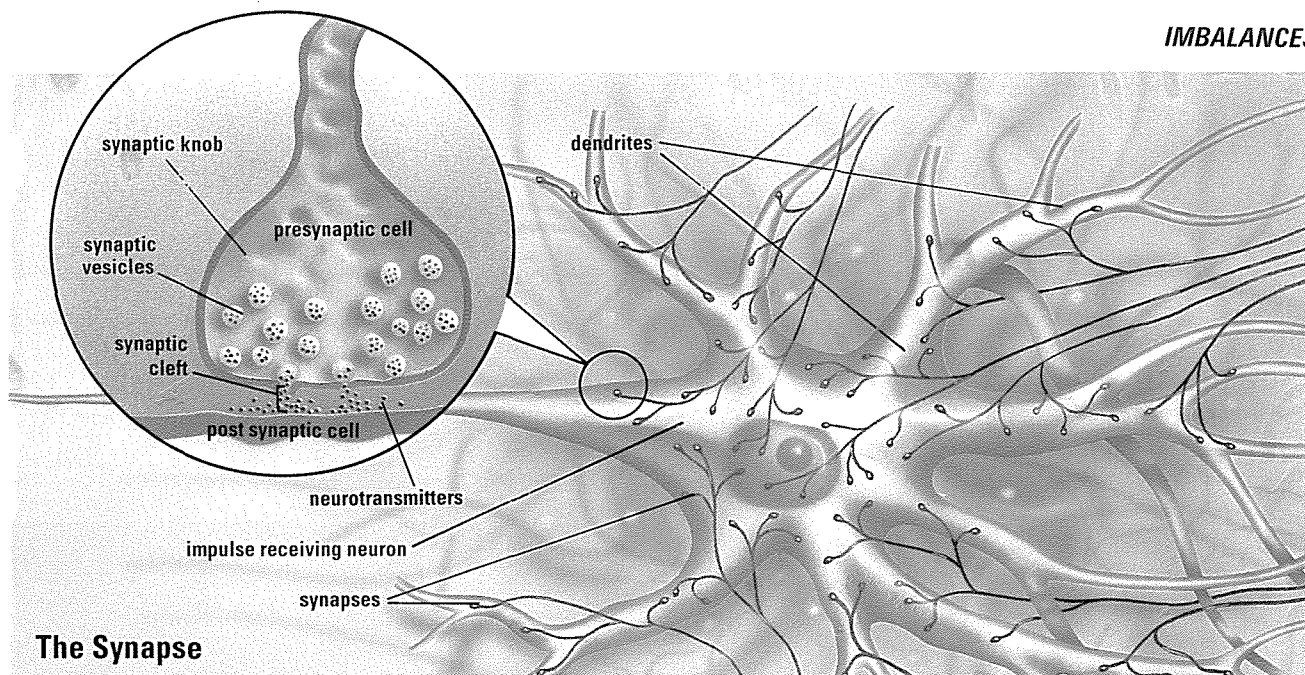


Supersport Photographs

Richard Smith



A step at a time. A child with cerebral palsy is taught by the 'conductive method'. This re-educates the undamaged parts of her brain to take on functions the damaged parts cannot cope with.



The Synapse

pass from blood to brain with ease. Many other substances are allowed no access, or only very slow passage through.

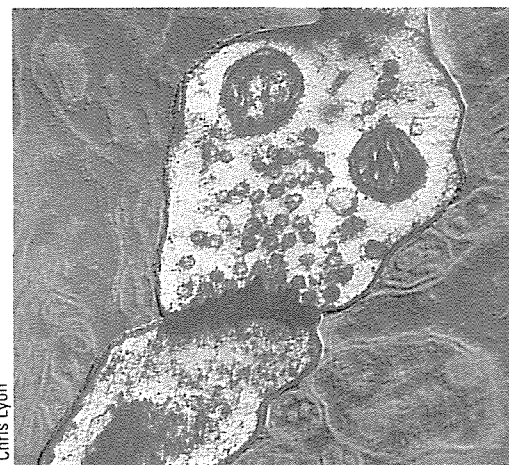
The barrier is thought to exist to protect and maintain the working of the brain, especially the neurotransmitters. This is because neurotransmitters would be that much less effective if they could diffuse throughout the body, instead of being kept relatively restricted to the central nervous system.

Mental chemistry

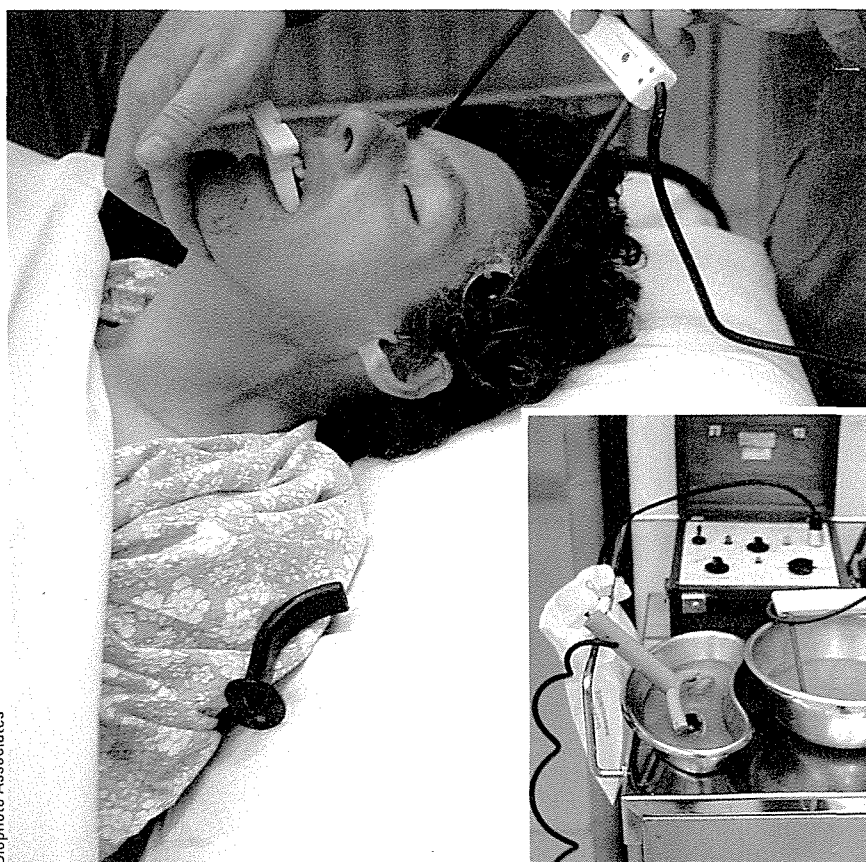
Neurotransmitters are chemicals and so also are drugs. A number of drugs are used to combat depres-

The synapse is where an electrical impulse from one nerve cell is passed on to another. The electron micrograph (right) shows the synaptic cleft as deep red and above it the vesicles (sacs) as red and yellow spheres.

sive illnesses. Common symptoms of such conditions are feelings of deep despondency and hopelessness. Some sufferers are known as manic depressives, since their moods also swing to elation and creativity. Drugs that increase excitatory transmitter substances in the nervous system, especially norepinephrine and serotonin, are



Chris Lyon

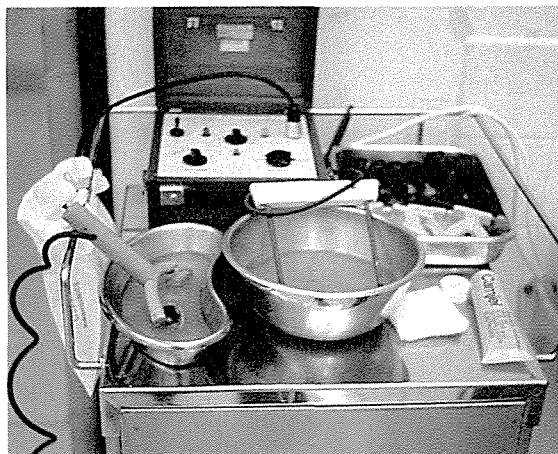


Biophoto Associates

often used to treat depression.

Parkinson's disease is one of the most obvious diseases related to chemical imbalances in the brain. Named after the surgeon who first described the condition in 1817, James Parkinson, the chief characteristic of the disease is a continuous and noticeable shaking of the limbs and impaired control over everyday, voluntary movements.

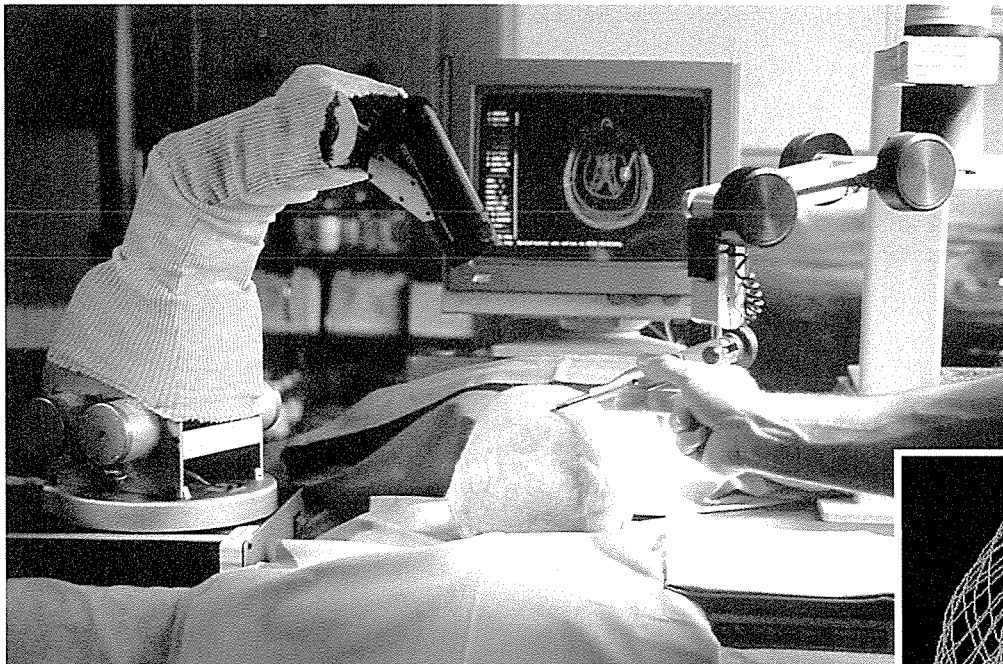
The root of the problem lies in the forebrain at the basal ganglia, where there are pathways both to and from the autonomic nervous



Biophoto Associates

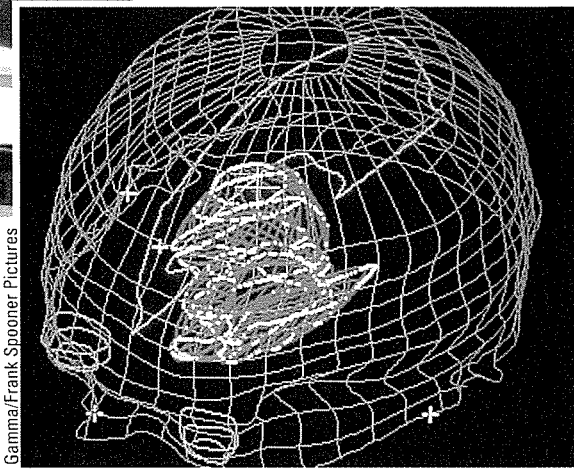
'Shocking treatment' is how ECT (electroconvulsive therapy) is often thought of. It 'cures' severe depression, but the price is a loss of some memory: 70-130 volts can be applied through electrodes while the patient is fully anaesthetized.





Surgery by robots; computer by man. A 3-D scanner provides a see-through image of the skull and brain (inset below). This enables doctors and surgeons to pinpoint the exact location for surgery or radiotherapy. Thanks to a micro computer, surgeons can use the image interactively to guide a surgical robot when operating on the brain.

Gamma/Frank Spooner Pictures



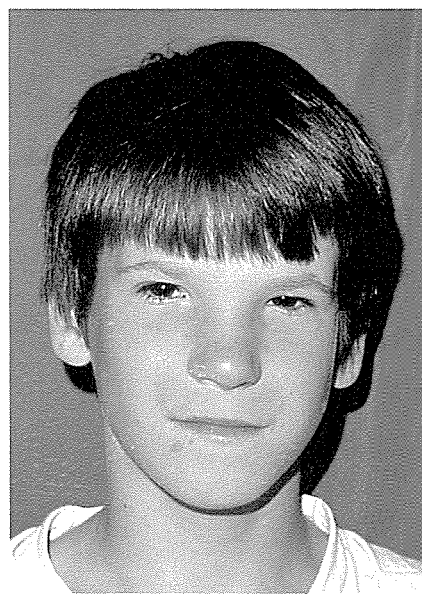
Gamma/Frank Spooner Pictures

system, the cortex and the limbic system.

The transmitter substance, dopamine, which is largely responsible for transmission of nerve impulses in this area, seems to be depleted increasingly as the disease progresses. This leads to random firing between neurons, causing unnecessary skeletal movements, for example. It has been found that injections of dopamine are quite useless, since the protective 'blood-brain barrier' does not allow the dopamine to pass to where it is needed. Drugs that increase the rate of dopamine release do help.

Abused by alcohol before birth, the young boy shows the flattened face symptoms of Foetal Alcohol Syndrome. Excessive alcohol can prevent the full growth of nerve cells in the foetus and can lead to a mentally handicapped baby.

Scientists are hoping that foetal tissue, taken from aborted human foetuses may offer a long lasting cure. Foetal transplants involve injecting undeveloped cells into the diseased area of the brain. As they grow and mature, they produce the dopamine that the damaged cells cannot.



Prof Sterling K Clarren

Schizophrenia is a mental disorder that, although having no clearly definable origin, does seem to have an organic cause involving neurotransmitter substances. Sufferers experience hallucinations and delusions.

Drugs that seem to be able to help cure schizophrenia are now known to block dopamine receptors in the brain.

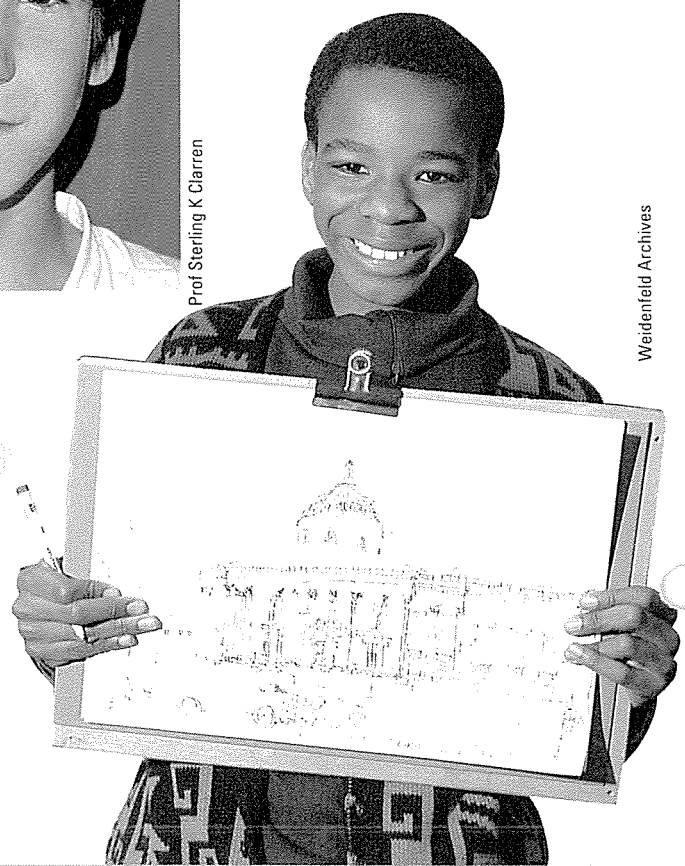
Just amazing!

DOES IT HURT?

WHEN THEY LOST THEIR LIMBS IN WORLD WAR II, SOME SOLDIERS FELT NO PAIN FOR A WHILE - NEUROTRANSMITTERS MAY HAVE BLOCKED PAIN RECEPTORS IN THE BRAIN. THE EXCRUCIATING PAIN RETURNED LATER.

Paul Raymond

Super talented and severely handicapped, Stephen Wiltshire produces architectural drawings of exceptional draughtsmanship. But he is also autistic. Doctors cannot explain why certain mental handicaps go hand in hand with remarkable talents in other fields.



Weidenfeld Archives

WHITE NOISE

VISUAL DEPRIVATION

DISORIENTATION

BRAINWASHING

IMAGINE THAT YOU KNOW something that must be kept secret. Then imagine that you have been captured by people who want to know your secret.

They lock you up; they frighten you. They force you to go hungry; they won't let you sleep. As time passes, you become more and more confused. Eventually, you are so desperate for them to leave you alone that you tell them the secret. The way in which the secret was obtained is called brainwashing.

In everyday life, you make sense of the world by comparing your brain's store of knowledge with information gathered by your senses — your ears, eyes and so on. A good example of this is the fluid in your inner ear. This is used to tell the brain whether you are standing up or lying down. If you spin round and round, your brain can't tell what is going on and you feel dizzy. Dizziness is the brain's way of telling you to stop.

In brainwashing, people do the same sort of thing to all your senses. When this happens, your brain can't work properly. The only way it can sort the problems out is to try and stop what is confusing it.

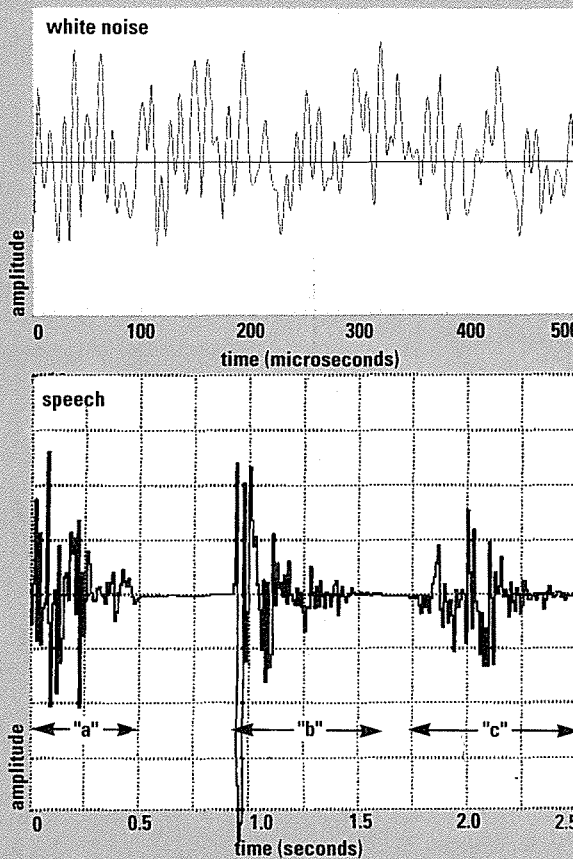
If it believes that the confusion will stop if you do certain things, then it will tell you to do those things.

The method that the brainwasher uses to cause this confusion is called 'sensory deprivation'. One way is to use 'white' noise. This is

like static on the radio. It constantly changes in volume and in frequency. When white noise is used in a certain way, the mind cannot make sense of what it is hearing.

Visual deprivation — depriving a person of their sense of sight — is

WHITE NOISE — SOUND WITHOUT SHAPE



The horrible hiss between stations on an FM radio is white noise. Like white light, it consists of a mixture of wavelengths.

The sound of white noise confuses prisoners because they cannot detect any recognizable pattern in it. In speech, however, we can detect differences in how each sound starts, continues and then dies away.

David Appleby/Warner Bros

Wandel & Goltermann

Dr D J Parish

Undermining physical well-being, through starvation and lack of comfort, is designed to reduce a prisoner's ability to cope with psychological assault.



INTERROGATION

A clever interrogator does not need to terrify or brainwash anybody. He or she can usually gain a person's confidence by using various tried and tested interrogation techniques.

First the prisoners are separated. Questioning starts immediately afterwards, before the prisoners have a chance to gather their wits.

This gives the interrogator an initial advantage, which he or she follows up by quoting a few facts that imply the whole conspiracy has been exposed. All that remains is to fill in a few details. Once the process has started, the interrogator is not brutal – simply firm and remorseless, giving the prisoner the feeling that there is no way out.

another technique used to disorient and confuse. The most simple method is known as hooding, and involves covering the prisoner's eyes. A more sophisticated technique is to place the person in a room in which all straight lines have been removed so that it is impossible to tell where the walls, floor and ceiling begin or end.

Sensory deprivation is most effective when all the senses are attacked at once. One way of doing this is to place the prisoner in an enclosed, soundproof tank of warm, salty water. Enclosing the tank produces total darkness so the eyes cannot function. Soundproofing it deprives the ears of any stimulation. Floating the person in water (the high salt content provides buoyancy) destroys the sense of balance. The water is even kept at the same temperature as human blood, so the brain cannot work out where the body ends and the water starts.

Strangely enough a short period of time, say 20 minutes, in a tank under these conditions is very relax-

ing – so much so that it is sometimes used therapeutically to induce a deep sense of relaxation. However, a long period – 24 hours or more – spent in a flotation tank can reduce a trained soldier to a gibbering wreck.

For brainwashing to be fully effective, sensory deprivation techniques are combined with other, more traditional, methods of ill treatment, such as starvation, fear and lack of sleep. Undermining the body's physical well-being in this crude way reduces the brain's ability to cope with psychological attack.



Humiliation

Lack of food becomes an obsession after a week, so the interrogator can start to control the prisoner by offering small amounts of food as a reward for doing humiliating tasks.

Brainwashers further increase fear and psychological distress by using hallucinogenic drugs such as lysergic acid diethylamide. Known as LSD for short, this chemical acts by magnifying a person's fantasies

and fears to huge proportions.

While it is surprisingly easy to brainwash a person, it is also easy to go too far and destroy them mentally, particularly when using chemical methods like LSD. One excess dose has been known to push a victim over the edge into madness and cause permanent brain damage.

Prolonged use of sensory deprivation techniques can result in mental breakdown, from which full recovery can only be made slowly. The brainwasher, therefore, has to be careful not to damage the subject so badly that he or she cannot reveal information or do what the brainwasher wants.

All the types of brainwashing developed so far wear off after a period. If the victim is given reassurance and security, preferably in reassuring conditions and with people that he or she knows well, recovery will soon follow.

Aircrew and members of elite military units, such as the French Foreign Legion or the Russian spetsnaz troops that operate behind



Warner Bros/Kobal Collection

Loss of all sense of reality is the result of a prolonged period of sensory deprivation.

Cult groups are alleged to use methods close to brainwashing to make their members conform. Leavers sometimes have to be 'de-programmed' so they can return to normal life.

the enemy frontline, are all trained to resist brainwashing. Everyday training for this sort of military personnel is fairly tough – but the only way to prepare them for brainwashing is to give them a realistic taste of it. Therefore they are hooded and put in isolation by their own side.

These soldiers are also taught simple techniques, including how to resist friendly advances from the interrogators. The interrogators often work in pairs – the junior acts brutally, while the senior offers some protection and a promise of relief in exchange for collaboration.

So far it has been found that once a man has been broken down physically, such resistance techniques are forgotten and, in the end, all that matters is relief from pain.

Note The techniques described here must not be tried out under any circumstances.



Rex Features



STOCKS IN TRADE

COMPUTER BROKERS

MONITORING MONEY

MAJOR STOCK EXCHANGES world-wide are now computerized. Stockbrokers work mostly from their own offices, doing deals by phone and computer terminal, instead of meeting on the traditional trading floors of the exchanges to buy and sell shares.

The markets where shares are traded are called stock exchanges. The word 'stock', in this case, meaning government securities and shares in companies whose value can go up and down. If you want to buy or sell shares, you go to a dealer, called a stockbroker, who will do the deal in return for a fee.

Companies issue shares to the public in order to raise the money they need to expand their businesses. People buy shares as an investment. In return, they get paid a part of the company's annual profits, called a dividend. Investors

H-Tec SELLING



Image Bank

There are, in fact, two prices for each share: the buy price and the sell price. The market's sell price is always higher than the buy price.

Automatic trading

Stockbrokers buy and sell shares on behalf of investors. They have to deal through market makers, larger stockbrokers who hold quantities of shares for sale and who set the prices.

The key to all this is SEAQ (the Stock Exchange Automated Quotations system) operated by the London Stock Exchange, now called the International Stock Exchange.

The rise and fall of share prices can now be noted on screens. Computer graphics give an instant (and easier) visual guide than the columns of a newspaper.

Wall Street is the popular name for the New York Stock Exchange, a characteristically bustling market in spite of the computer aided trading.



Image Bank

The Tokyo Stock Exchange is a leading world market. Dealers overseas rise early in order to trade there – electronically.

Some 360 stockbroking firms are members of the Exchange which, in a year, handles the buying and selling of shares worth a total of about £1000 billion.

The shares of over 3,500 companies are traded on SEAQ, which has its main computers in the Stock Exchange building. Market makers key their buy and sell prices into the system on terminal keyboards in their own offices.

also hope that the value of the shares they buy will increase over the years, so that they can make a profit if they decide to sell them.

If a great many people want to buy shares in a particular company, the price of those shares goes up. But, equally, if many people want to sell, the price goes down.





Labelled and ranked like jockeys at their stalls, dealers on the Hong Kong Stock Exchange sit poised in front of their screens to trade in shares.

Time watching is essential since the world's major stock exchanges are linked to each other by satellite and deals can be made round the clock.

With an electronic dealing system, stockbrokers can simply key in their buy and sell orders on their terminals. The deal is then automatically processed by computer.

Electronic dealing

When using these systems, brokers have to buy from (or sell to) the market maker operating it. But the operator guarantees to match the best prices on offer from the other market makers, so brokers can be sure of making a fair deal for their clients.

Another system called SAEF (SEAQ Automatic Execution Facility) is operated by the Stock Exchange itself. SAEF went 'live' in

In the USA, NASDAQ (National Association of Securities Dealers Automatic Quotation system) is an enormous network of computers and terminals, linking the offices of thousands of share dealers (stockbrokers and market makers) all over the United States and around the world.

The American way

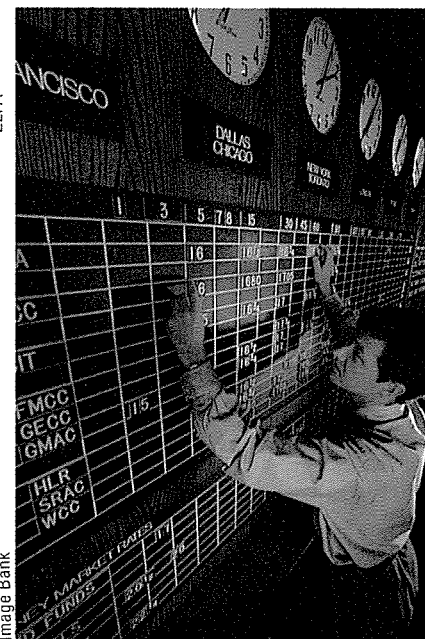
NASDAQ lists the shares prices of about 5,000 American companies. Its terminals are installed in over 6,000 dealers' offices in the USA, and there are over 8,500 terminals installed in other countries.

It is also possible for individual investors to be linked to the system – over 100,000 already are. They pay a subscription and get basic share price information via a small computer terminal.

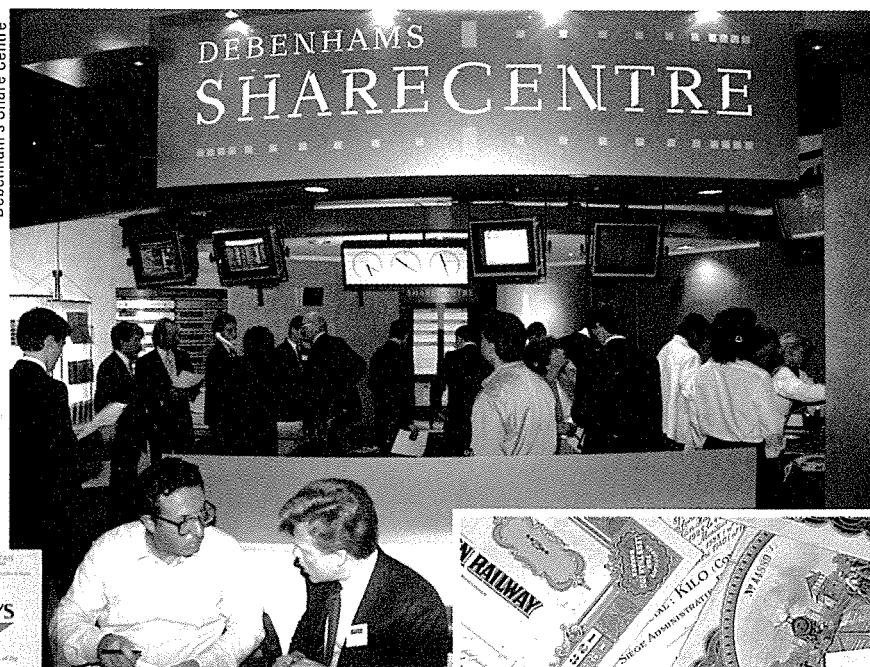
When SEAQ first came into use in the UK, a broker wanting to buy or sell shares in a company would call up the details on his own terminal. The screen would show him the buy and sell prices offered by all the market makers dealing in those

particular shares. Then he would choose the one offering the best price and phone up to make a deal.

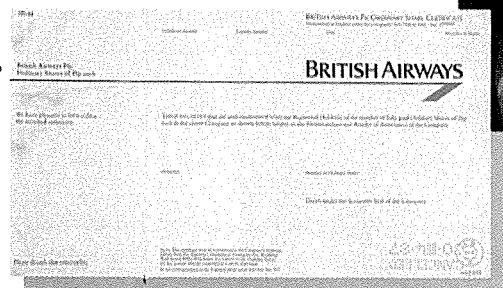
This method is still used, but brokers can now also buy or sell automatically, by using one of the new electronic dealing systems.



Share shopping has been made much easier in Britain with the introduction of 'share shops' – independent dealers who can buy and sell shares for anyone who cares to buy during a normal shopping spree.



Slim and simple, today's share certificate is available to a wider public, in contrast to the elaborate bonds (inset right) once issued to an élite.

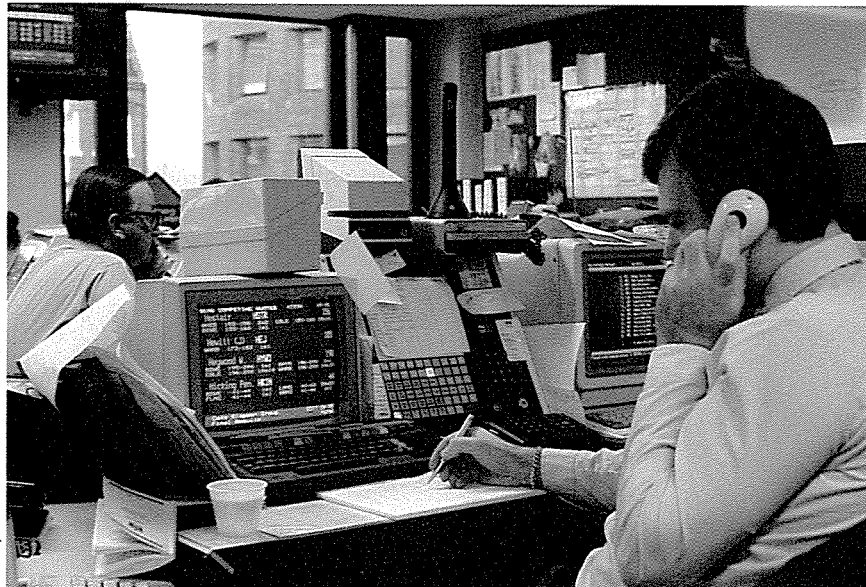


Hawking shares on the floor of the International Stock Exchange in London. Stockbrokers can now act as market makers – holding supplies of shares for sale to other brokers – and as agents for investors, simply buying and selling on their behalf. Before the 'Big Bang' in October 1986, only jobbers, distinguished by the top hats they wore, were allowed to make markets in shares on the floor of the exchange.

A computerized stock market means that stockbrokers are kept in instant touch – not only with the changing prices of their own stock market, but also with those of stock markets around the world. Most dealing is now done straight from the dealer's desk by telephone, leaving the exchange's floor a less busy place than before.



International Stock Exchange Photo Library, London



Peter Ryan/Science Photo Library

February 1989 and all the market making companies on the Exchange are linked into it. The only equipment a broker needs is a terminal (any IBM compatible personal computer) with a printer, linked to the system via an integrated data network.

Unlike the other systems, which are offered free to brokers (because the operators get the commission on all the deals made through them), brokers have to pay to use SAEF. They pay a fee of about £2000 to join the system, plus a few pence for each deal they make on it.

When a broker keys a buy or sell order into his SAEF terminal, the central computer finds the market maker offering the best price and makes the deal automatically. There is no need for the broker to check all the different market makers' prices,

then phone the one he wants to deal with.

When the SAEF computer has done the deal, it sends a message to the broker's computer telling it what the deal was. The message appears on the computer screen and is also printed out.

Information

A company's share prices can be affected by all sorts of things, apart from the way its business is performing: politics, wars, strikes, crime, the activities of rival companies and even the weather. So, brokers and market makers need up-to-date news and information to help them make their business decisions.

To meet this need, many electronic information systems have been set up. The information is sent by

MONEY TALKS

In the fast and furious world of trading on the international stock markets, a language of its own has evolved.

Alpha shares: the 100 most actively traded shares on the International Stock Exchange, London.

Arbitrageur: someone who buys shares, commodities or currencies in one market to sell at a profit in another.

Bear: someone who thinks share prices are about to fall.

Bull: someone who thinks share prices are about to rise.

Gilts: short for Gilt Edged Securities issued by the British Government to raise money. They are valued in units of £100, pay a fixed rate of interest annually and can be cashed in after a fixed number of years.

Index: (as in the FT 100 Share Index and the Dow Jones Industrial Average): a calculation based on the changes in the values of a number of selected shares.

Listed company: a company whose shares, listed by the Stock Exchange, can be bought and sold there.

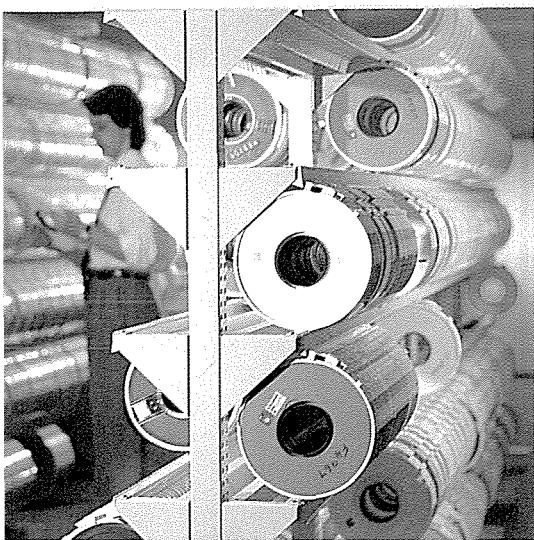
Portfolio: a selection of shares owned by anyone.

Security: a general name for stocks and shares.

Stag: someone who buys newly issued shares in the hope of making a quick profit.

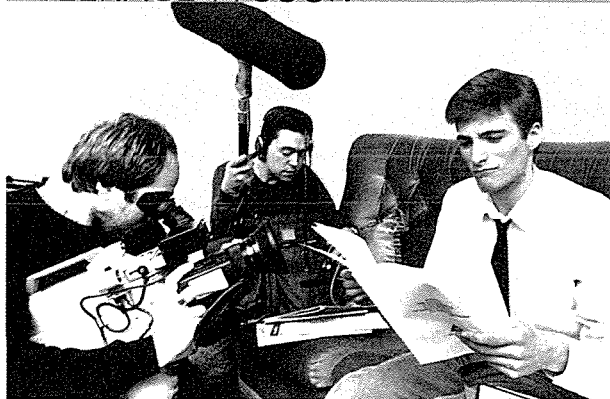
Stock: usually means shares, particularly in the USA. Fixed interest stock (like gilts) pays a fixed rate of interest over a fixed period.





Taped for future reference. Details of all transactions are stored on computer tapes at the International Stock Exchange, London, for use on the mainframe computers. This means that any illegal dealing can eventually be traced back to unscrupulous dealers.

TEENAGE TYCOON



In November 1987, British schoolboy Christopher Peach, 15 years old, made headlines when he lost £20,000 on the Stock Exchange. He made the deals from a public telephone during school breaks, having managed to raise credit of over £100,000. Unfortunately, when the market crashed in October 1987 so did his portfolio. In 1988, he tried to take over a finance company, but his offer was rejected – because of spelling mistakes.

Ron Duggins

cable to terminals rented to the systems' subscribers. As well as brokers and market makers, subscribers also include banks, insurance companies, newspapers and radio and TV stations.

Up to the minute

The International Stock Exchange has a system called TOPIC (Teletext Output Price Information Computer), which carries share price information, Stock Exchange announcements and company news. Other systems include those operated by the financial information service Extel, and by the Reuters news agency, which provides several services.

Reuters Monitor, for example, has over 50,000 terminals worldwide. The Reuter Monitor Capital Markets Service contains 2,500 pages of information, which are regularly updated from over 400 sources.

Reuters also operates a number of interactive systems, which en-

Mainframe computer banks – the central processing units at the International Stock Exchange – process data fed from tapes according to specific computer programs.



International Stock Exchange Photo Library, London

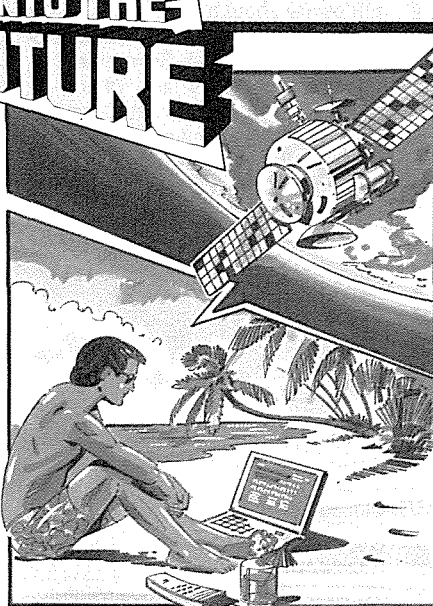
able subscribers to buy and sell shares electronically. These systems are popular with dealers whose local stockmarkets do not yet provide electronic trading, but they also compete with many existing trading systems.

Back in the USA

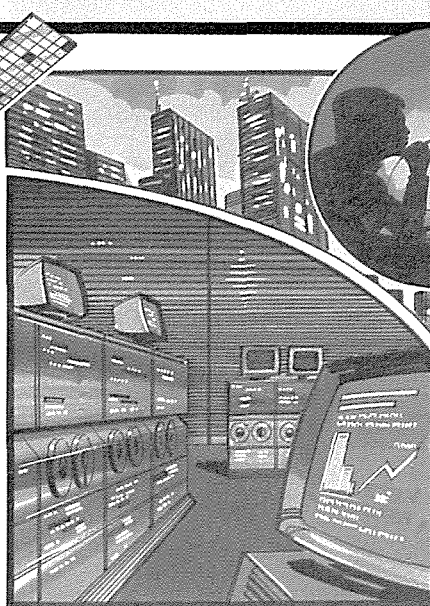
In the USA, Reuters operates a system called Instinet, which lists over 8,000 American shares. Instinet's main rival in the United States is the Telerate system, which has more than 15,000 subscribers. Telerate is owned mainly by the Dow Jones company, who are the publishers of the famous *Wall Street Journal*.

INTO THE FUTURE

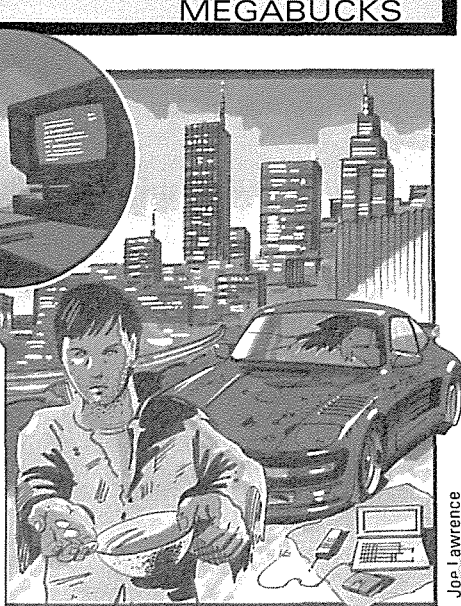
MEGABUCKS



▲ When all the international electronic trading systems are linked via satellite to a single terminal, dealers will be able to operate anywhere – and at any time.



▲ To free them from being tied to their terminals 24 hours a day, the computers could be programmed to trade independently within a set limit of prices.



▲ Fortunes could be made automatically round the clock – but also lost, if hackers managed to infect the system with mischievous computer viruses.

Joe Lawrence



SLOT MACHINES

- FAKE COINS
- ELECTRONIC CHECKS
- COMPUTER LINKS

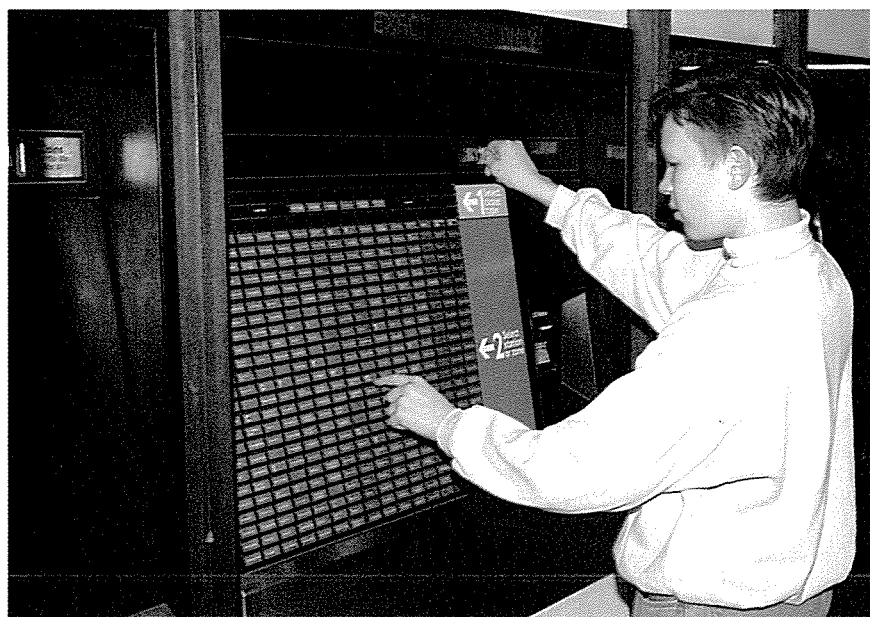
WAR GAMES, HOT FOOD, fortune telling and phone calls are just a few of the things available from slot machines. These machines range from simple, coin-operated units to computerized machines that take coins, banknotes and even credit cards.

When you use a coin-operated slot machine, it first has to check that you have put in the right money. Each coin goes through several tests, and if it fails any of these it is dropped into the reject chute.

In a small mechanical machine that can take only one type of coin, the slot you put the coin into provides the first test. Any coin that is too big will not go into the slot.

The second test usually involves measuring and weighing the coin. From the slot, the coin drops into a pair of hooked arms on a vertical metal plate, pivoted near its centre. If the coin is too small, it drops straight through the arms and into

Barnaby's Picture Library



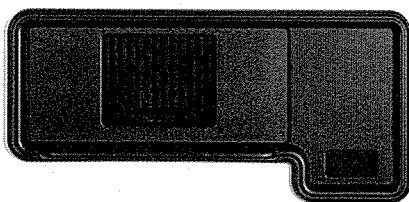
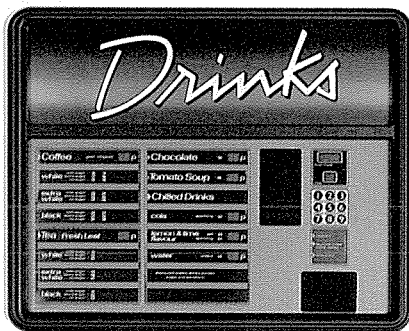
Many slot machines attract customers with cash prizes, but the opportunity to control spacecraft and blast aliens is proving addictive too.

Some ticket machines have a button for each station. On selecting the type of ticket and your destination, the machine tells you how much to pay.

the reject chute. But a coin of the right size will be caught between the arms. Then its weight will make the metal plate rotate about a quarter of a turn, tipping the coin forwards into the next stage of the mechanism.

A coin that is too light will not





Instead of cash, this machine accepts payment by plastic card, allowing up to 14 customers to be served in one minute.

make the plate turn. Instead, the coin will be held between the arms until you press the reject button. This will cause the plate to pivot backwards, dumping the coin into the reject chute.

These checks can only tell the machine that the piece of metal it

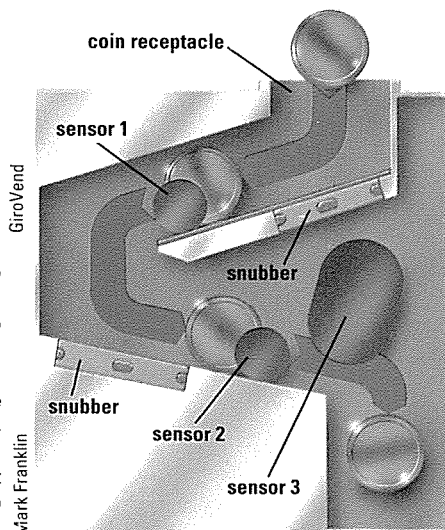
has been checking is of the right size and weight. They cannot tell it whether it is a real coin or not. To find that out, the machine rolls the coin down a slope past a magnet.

When a piece of metal moves through a magnetic field, electric currents called eddy currents are set up in the metal. These currents in turn create their own magnetism — even if the metal is one that cannot normally be magnetized.

As a result, the coin becomes temporarily magnetic when it rolls past the magnet and experiences a force of attraction to the magnet. This causes the coin to slow down as it passes the magnet. The amount by which it is slowed down depends on the strength of its magnetism and this, in turn, depends on what metal it is made of.

Detecting fakes

After passing the magnet, the coin drops off the end of the slope. The angle at which it falls depends on its speed and, if it does not drop at



GiroVend

Mark Franklin

Signals from sensors in modern slot machines are used to check coins for thickness (1), material (2) and size and shape (3). Snubbers reduce coin bounce.

the correct angle, the coin will be rejected. If it does fall at the right angle, the machine will operate and give you what you have selected.

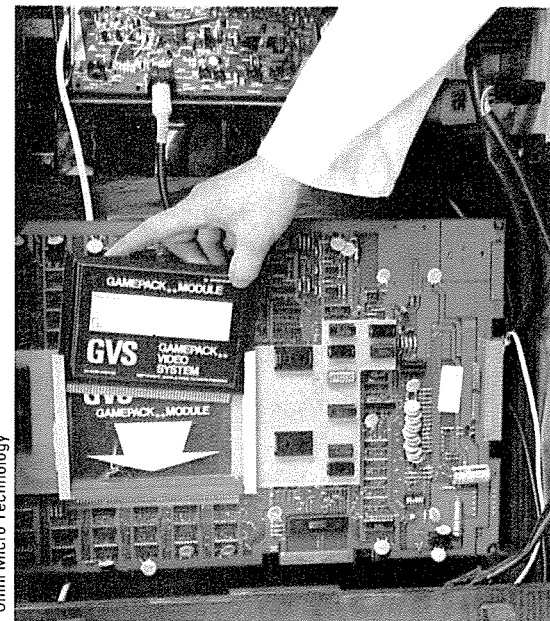
The mechanism is set up so that only genuine coins will pass this test. Fakes, made of the wrong metal, will be slowed down either too much or too little by the magnet. So they will drop at the wrong angle and fall into the reject chute.

Larger machines, especially those that can take a range of coins, add up their values to check how much has been paid and are often designed to give change.

Controlled by chips called microprocessors, these machines use light beams and light-sensitive electronic components to measure the size and thickness of the coins, and

to measure their speed as they pass through the magnet section.

Some machines accept notes as well as coins. The notes are fed into a slot, short edge first. The machine shines a light on to the note and, using light sensors, it compares what it 'sees' with the pattern of a good note stored in its memory. If



Omni Micro Technology

Arcade games machines, like many home computers, can be made to play various games simply by inserting different program cartridges.

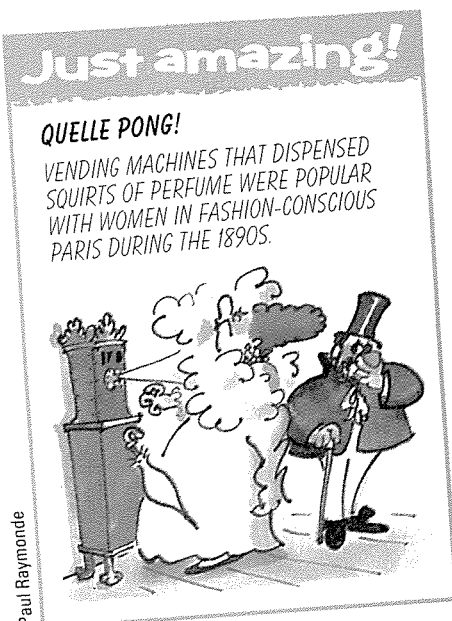
the two match, the machine accepts the note; if they do not the machine rejects the note.

The latest generation of ticket machines, such as those installed in many underground stations, take a wide range of coins and also give change if necessary. Most of these machines are for passengers who know their destination.

To use the machine, you press the button for the ticket you want, then put your money in. Coins of various values can be inserted, in any order, and the machine will give change if necessary. The machine prints the ticket after cutting it from a continuous roll of card and also records details on a magnetic stripe for use in automatic ticket barriers.

Computer networks

In major cities, underground train ticket machines are linked to local computers, and these are linked to a central computer system. Through this computer network, the machines report how much money they have taken and how many tickets they have sold. They also report any faults that might have developed. This information on passenger numbers and maintenance requirements is available to transport controllers at any time, thus helping to ensure a more efficient underground system.

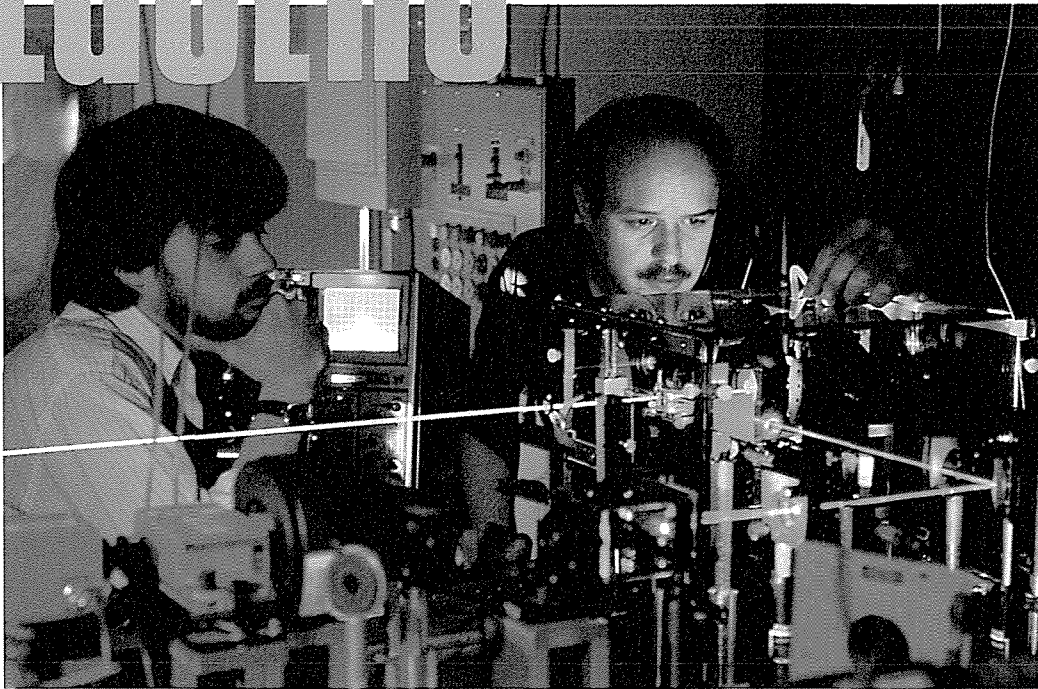


Paul Raymonde



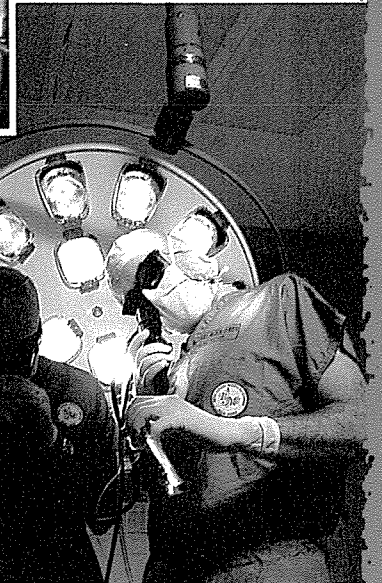
LASERS — HIGH ENERGY LIGHT

Hank Morgan/University of Massachusetts at Amherst/SPL



Researchers at work with a laser beam produced by crystals of Yttrium-Aluminium-Garnet, which are sandwiched between plates of the rare metal Neodymium. Y-A-G crystals are also used to make fake diamonds.

Endoscopes — flexible fibre optic tubes — are used to convey laser beams into the body and allow surgeons to work on tissues and organs without having to cut a patient open. TV screens show how the work is progressing.



Alexander Tsiras/SPL

KILLER RAYS

MEDICAL MIRACLES

VERSATILE TOOLS

A SURGEON BLASTS AWAY fat clogging the arteries of a heart disease victim, using infra-red laser radiation shone through a tiny fibre-optic tube. Operations such as this could soon be standard practice in hospitals around the world.

Lasers often hit the headlines because of their uses in weaponry, but they have a great many other important applications. They have, for instance, a major role in medicine already.

Since the first one was made, in 1960, lasers have come a long way.

In fact, most people have had some dealings with a laser — whether it's the one in a compact disc player, or one used to carry a long distance phone call down an optical fibre, a bar code reader at a supermarket checkout or a light show at a concert. Lasers still have great potential for development and their new applications are continually being discovered.

The name 'laser' is short for Light Amplification by Stimulated Emission of Radiation. The radiation in question may be visible light, or it may be invisible radiation such as infra-red light, ultra-violet light or even X-rays. All these are forms of what is called electromagnetic radiation.

How lasers work

The gas-discharge laser is a good example of how lasers work. A gas, such as carbon dioxide or argon, is

contained in a tube with a mirror at each end and has an electric discharge (current) passed through it.

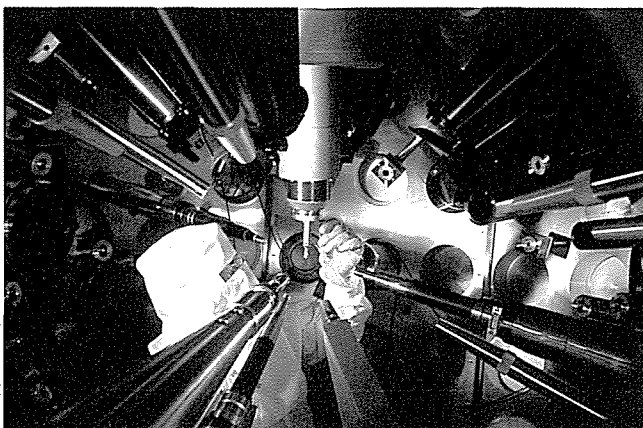
The electric discharge gives energy to the gas atoms and they become what is known as 'excited'. To calm down again, they lose the energy by emitting a photon — a 'particle' of light. This process is the 'stimulated emission of radiation'.

If an excited atom is hit by a photon before it has time to lose its own energy it emits another, identical, photon. If the photon hits a non-excited atom it is absorbed by it, and so is lost.

If over half the atoms are excited, the number of photons produced is higher than the number of photons that are absorbed by non-excited atoms. The radiation (light) is thus amplified — this is the 'light amplification' part of the name 'laser'.

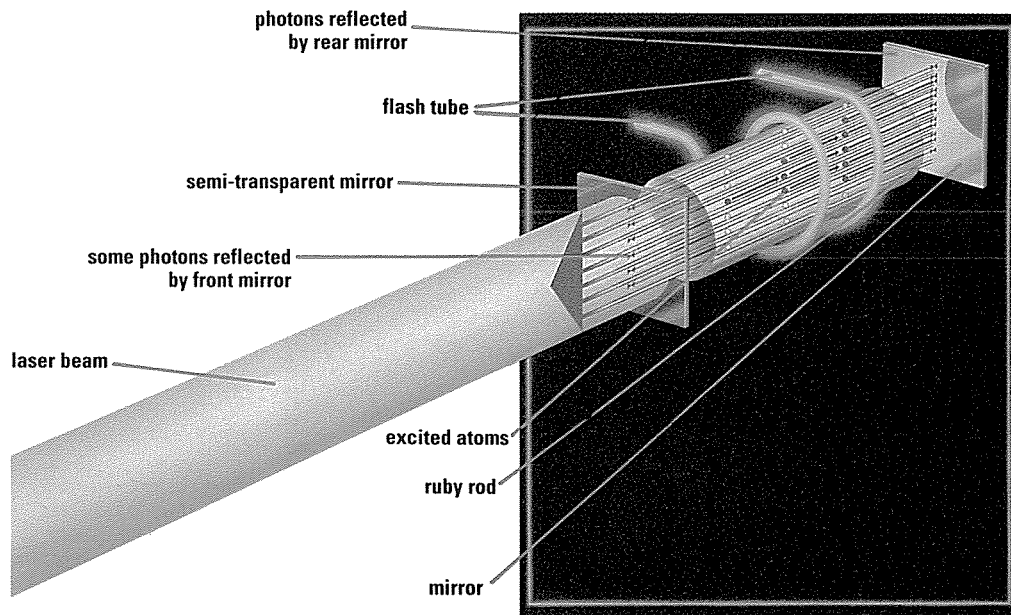
The mirrors at each end of the tube reflect the photons backwards

Nuclear fusion is achieved by heating and pressurizing hydrogen isotopes. The Phebus system uses up to 24 separate lasers, which are focused on a frozen pellet of hydrogen in a chamber. For a fraction of a second, this produces conditions like the interior of the Sun.



Philippe Plailly/SPL





A rod of ruby – better known as a jewel – is often used to make crystal lasers. Light is fed in from the discharge tube, which creates an intense series of flashes. These raise the atoms of the crystal into an 'excited' state, so it gives off photons that buzz back and forth between the two mirrors, until they escape in a narrow, intense beam.

A 'rainbow tunnel' is one of the big attractions at the Epcot Center, part of Disneyworld at Orlando in Florida. Lasers fire down fibre optic tubes, which arch over to form a multi-coloured walkway to guide visitors into the world of the future.

and forwards within it, creating a parallel beam of photons. Keeping the photons bottled up within the tube like this increases the number of them available to create even more photons.

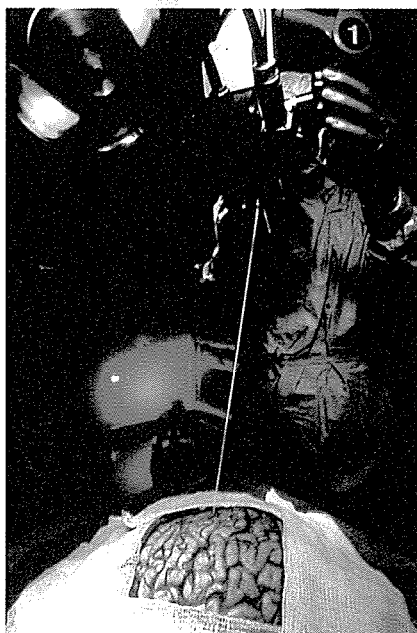
However, one of the mirrors is only partly reflecting. This allows some of the photons to escape, forming a parallel beam of single-frequency laser light. The fact that the light is all of the same frequency is one of the special features of a laser. (Ordinary light is usually a mixture of different frequencies.)

The frequency of a laser's light (and thus its colour) depends on what material is used to produce it. The frequency can range from very high frequency (short wavelength) radiation such as X-ray and ultra-

Argon lasers are used to vaporize brain tumours, cut out damaged sections of brain and anaesthetize pain centres. The heat minimizes bleeding and scarring.



ZEFA



Alexander Tsiras/SPL

violet radiation, through visible light, to low frequency, long wavelength infra-red (heat) radiation. A typical infra-red laser is one using carbon dioxide gas.

Another special quality is that the laser radiation is all in phase – all the waves are travelling in step. This is different to the waves of ordinary radiation (visible light, for instance), which are out of step with each other.

Because it is all in phase, laser light is called coherent light, and its coherence makes it highly valuable as an accurate and powerful tool. For instance, coherent light forms tight beams that don't fan out. This means that the power is concentrated in a small area. Unlike the light from an ordinary 60 watt light bulb, which won't do you much harm, a 60 watt laser beam could quickly burn a hole through you.

There are many types of laser,

Just amazing!

TIMED TO PERFECTION

MEASUREMENTS OF THE EARTH'S DIAMETER ACCURATE TO 20mm ARE MADE BY BOUNCING A LASER OFF A SATELLITE AND TIMING THE TRIP.



Paul Raymonde



including solid state lasers, gas-discharge lasers, pulsed gas lasers, semiconductor lasers, chemical lasers and dye lasers. They range in power from a few thousandths of a watt or less, to many millions of watts, and deliver their power in either a continuous beam or in pulses.

The huge number of uses for lasers include welding, cutting, drilling, engraving, sending digital signals down optical fibres, the production of holograms, playing compact discs, printing and creating head-up displays in cars and aircraft. They are also used as the basis for many surveying and engineering instruments.

Medical lasers

Many of the most interesting uses of lasers, though, are in medicine. In hospitals, lasers are increasingly being used in place of more traditional surgical implements such as scalpels and knives. They never get blunt, they don't need to be sterilized and the heat they produce seals the cuts they make and so reduces bleeding.



Allsport

Maurice Hope (right) kept his World title after the retina in his eye was 'welded' back into place using a surgical laser.

The AGM-65B Maverick air-to-ground missile is guided by a laser beam fired at the target by the launch aircraft.

by the eye's lens, on the retina at the back. There, it makes a tiny spot-weld to fix the retina back in place.

Lasers are also effective at removing skin blemishes, including warts, 'port wine' birthmarks and unwanted tattoos. The energy delivered by a laser is very controllable and skin can be removed in wafer-thin layers. Some laser beams are harmless to ordinary skin and will be absorbed only by skin that is discoloured. A red skin mark, for example, will absorb the energy from a green laser beam while the surrounding skin remains unaffected.

New cancer treatments being developed include photochemotherapy.

Small scout helicopters cannot carry enough punch to knock out tanks fitted with carbon fibre armour. One solution is to use a laser-equipped scout helicopter to designate the target, which is then attacked with precision-guided missiles launched by heavy attack helicopters operating behind the forward edge of battle.

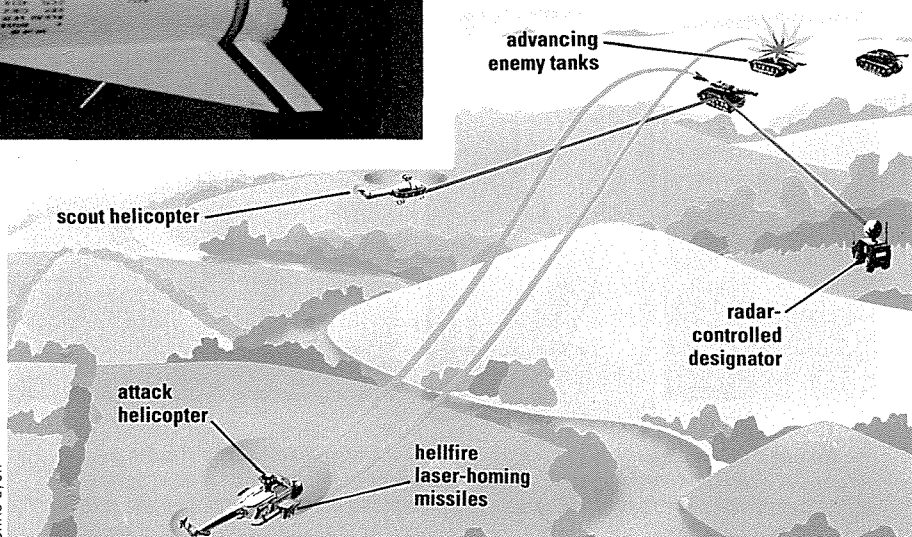
Department of Defense, US Air Force



They are also used for operations on places within the body where ordinary surgical tools would not have been able to reach. In addition, because of the nature of the energy they deliver, they can be used for tasks that were previously impossible.

For example, if the light-sensitive retina becomes detached from the rear of a person's eye, it can be welded back into place by a surgeon using an argon gas laser. The beam passes through the eye without harming it and is focused,

Chris Lyon



LASER-POWERED TRAVEL

Interstellar travel requires very high speed to keep journeys within the lifetime of human beings. So plans are being made to send a laser-powered spaceship to Epsilon Eridani, 10.8 light years away.

A group of lasers back on Earth will be focused by a massive Fresnel lens. The beam will then shine through space on to a circular three-stage sail 1,000 km across and blow the spaceship along. It will weigh 75,000 tonnes and accelerate to half the speed of light, giving a journey time of 20 years.

In this treatment, a patient with a cancer is injected with a drug that makes the cancer cells sensitive to light of a certain wavelength. Shining laser light of that wavelength on the cancer will destroy it.

The laser for photochemotherapy is shone down a fibre-optic tube. Incorporated in an endoscope (a thin, steerable tube that can be fed through openings into the body), an optical fibre with a laser shining in one end of it can deliver laser power to many internal parts of the body. Lasers are used in this way for many kinds of treatment, such as to stop stomach ulcers bleeding and to blast away pre-cancerous cells on the neck of the womb.

The light brigade

Designers are trying very hard to make lasers into effective weapons of destruction, in addition to their existing military uses in guidance and information systems. For example, laser-guided bombs have far

greater accuracy than visually-targeted bombs, while missiles guided by scattered laser light can home in with deadly precision.

Other weapons are used to blind or dazzle infantry or tank personnel with a brilliant flash of light, and lasers are also used as sights for weapons and in military exercises

to 'shoot' opponents. But lasers used to destroy targets require vast amounts of energy to power them.

The only power source large enough for this purpose is an atomic bomb. The idea is that a small bomb will be exploded underground and the energy focussed into a large discharge tube.

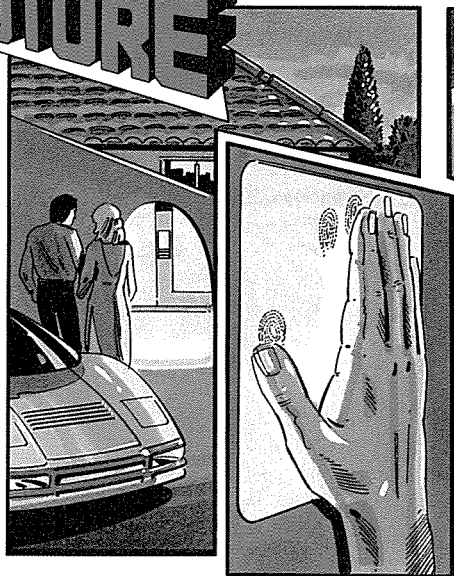


Jean-Michel Jarre's sound and light show has spectacular giant lasers linked into the sound system so that the lights dance in time.

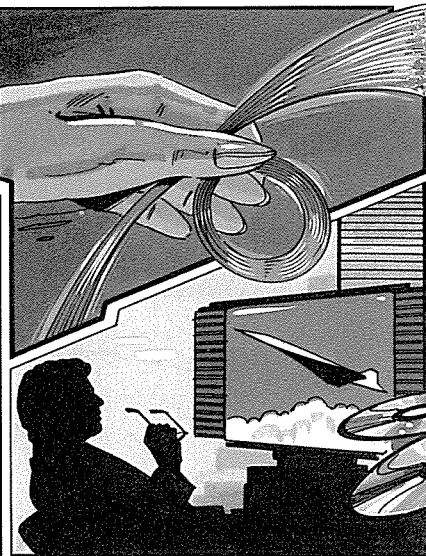
Lasers can deliver a narrow beam of heat energy powerful enough to cut right through metal. When used in metal workshops for cutting out complex shapes, the laser head is mounted on a machine tool called a profile cutter. The cutting beam is controlled by either a human operator or a computer.



INTO THE FUTURE



▲ No need to fumble for keys in the future. To open the front door, members of the family will pass their right hand over the scanning head of a laser.



▲ Newspapers will be transmitted direct to the home on a fibre optics cable and be printed out on the laser printer that serves all home computers.

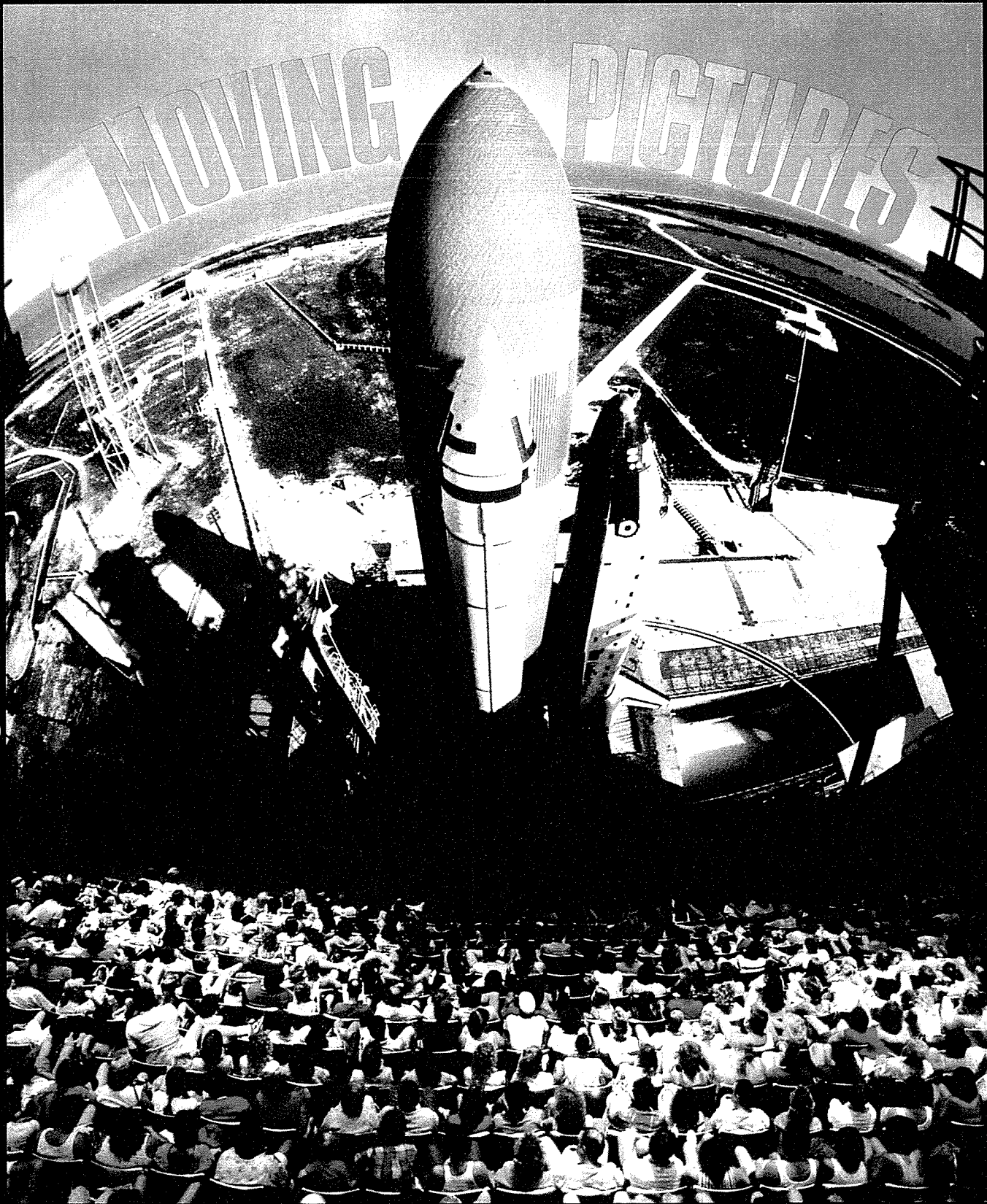


▲ Pupils will often work at home because all the books in the school library and many self-teach courses will be available on laser-read discs.

THE WIDEST SCREEN

ANAMORPHIC LENSES

EXTRA WIDE FILM



Inmax Systems Corporation

WHEN THE LIGHTS GO DOWN in the Omnimax cinema, the projection system takes the audience right into the action on the screen.

What the cinema actually shows are not, despite their name, moving pictures. A cinema film is simply a sequence of still pictures, basically similar to the ones you take when you're on holiday.

The pictures (or 'frames') are nor-

mally taken at the rate of 24 per second, and each one is slightly different from the one before. The pictures only seem blended together because of the speed at which they are shown on the cinema screen.

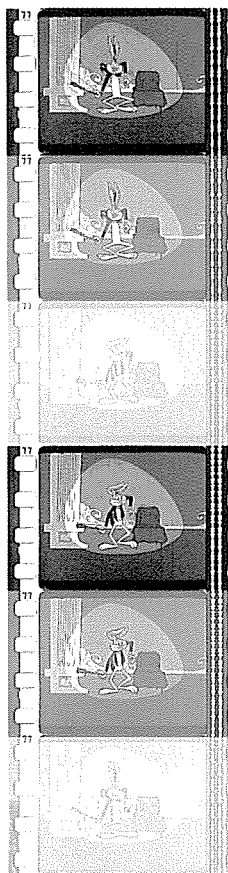
When we watch a film, our brains interpret the procession of still pictures on the screen as a single, continuously-moving image. If our brains were quick enough to pick

Viewers sit in reclining seats so that they can take in the whole picture projected on the giant dome-shaped screen of an Omnimax cinema.

out the different pictures on the screen, we couldn't have moving pictures in the cinema or on TV.

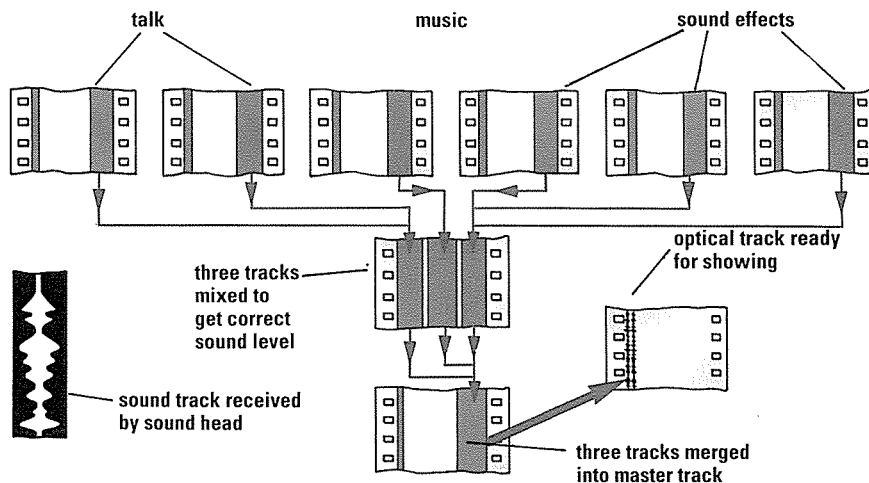
The basic principles behind movie equipment have not changed since movies were invented. In a cine





Film sound is made up from six tracks. The first two are the words, the next is the music and the final three sound effects. These are combined in one track and converted to an optical pattern on the finished film. The sound track is 20 frames in front of the pictures, so it can move at a constant speed.

Bugs Bunny, shot (like most films) on 35mm film at 24 frames per second. The optical sound track runs down one side, between the edges of the frames and the sprocket holes. As light passes through this, it is picked up by a photo-electric cell that converts the varying light intensity into sound.



Mark Franklin

Since standard cine cameras run at a speed of 24 frames a second, the projectors must run at the same speed in order to keep the on-screen action at the proper speed. (The reason many of the old silent movies look jerky and speeded-up is that they were filmed at a slower frame speed than modern projectors run at.)

Film projectors

The beam of light that projects the picture on to the cinema screen is focused by a system of lenses at the front of the projector. For showing, a copy of the processed film is fed into the projector through the

'gate', which guides the film as it passes between the light source — a powerful lamp — and the projector lens.

Below the gate is the intermittent, which holds each frame stationary behind the lens for an instant then moves it on. While the film is stationary in the gate, a revolving shutter between the light source and the film opens to let the light shine through the film and project its images on to the screen.

The shutter opens and closes two or three times while each frame of film is being projected. This increases the number of separate images flashed on to the screen

camera, a long, continuous strip of film is wound from one reel on to another, passing a shutter and lens.

When the camera is running, the film is stopped for a fraction of a second behind the shutter (which is blocking off the light from the lens). The shutter opens briefly, letting the light from the lens through to expose one image or frame on the film. Then the film moves on and the next frame is exposed.

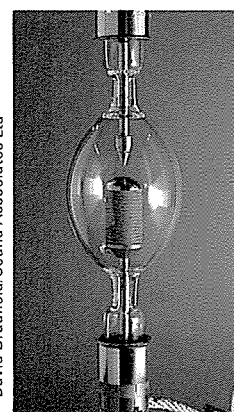
It's a frame up

The only time that light is allowed to get at the film is during the split second that it is immediately behind the lens and the shutter is open. This normally happens 24 times per second, which is enough to smooth out all but the fastest movements. Higher frame speeds (more frames per second) are used only for special purposes like slow motion and some types of special effect.

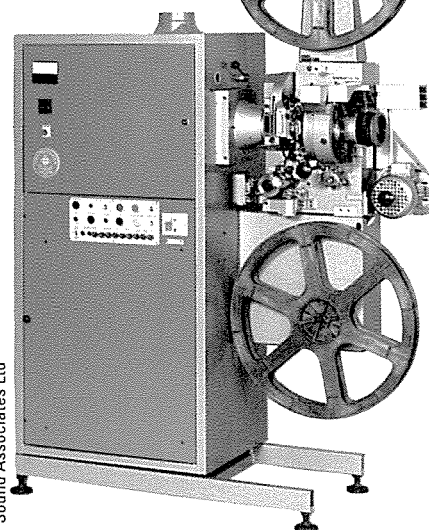
The film transport system that carries the film through the cine camera has a series of toothed wheels or sprockets. The teeth on these wheels fit into the sprocket holes up each side of the film.

When all the film on a reel has been exposed, it is removed from the camera and sent away for processing.

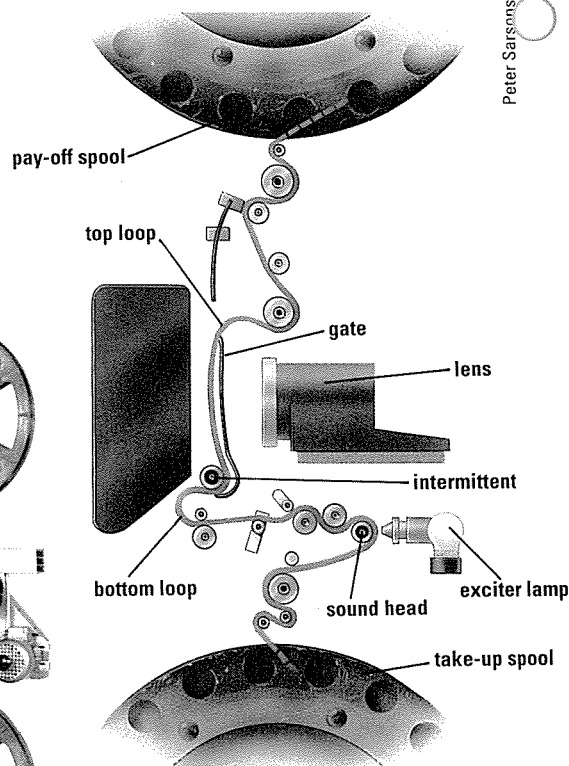
The scenes in films are not shot in order. A shooting schedule is drawn up before filming starts, depending on when the stars are available. The day's films are developed overnight and prints are made to check results — these prints are called the 'rushes'.



David Bradford/Sound Associates Ltd

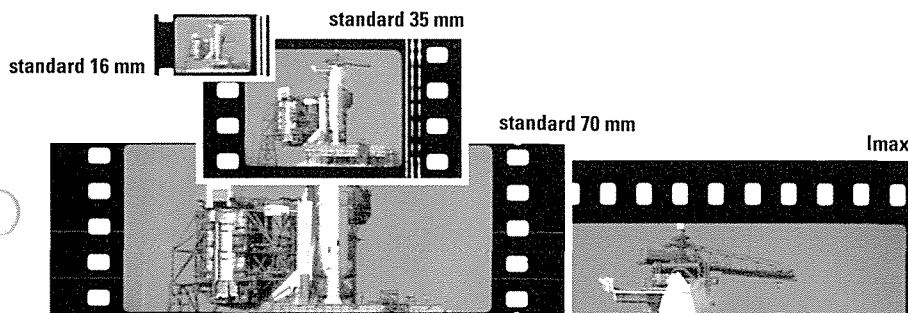


Sound Associates Ltd

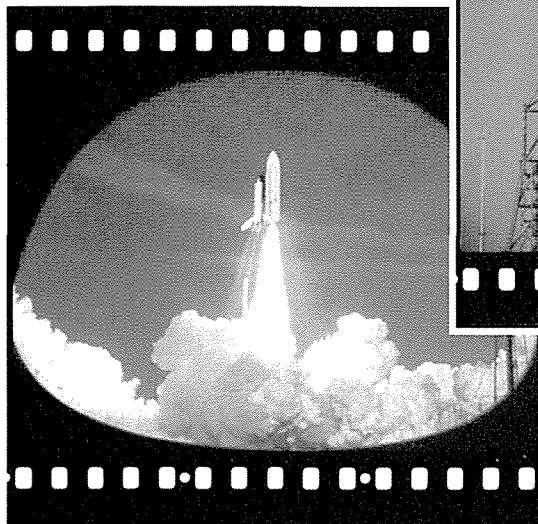


Peter Sarsons

Cinema projectors are taller than a man. The body of the projector contains the sound equipment, plus the Xenon light source (top left). The film is carried on sprockets, while the intermittent lines each frame up with the lens and pulls it through the projector.



Omnimax



Most films are shot on 35 mm stock. 70 mm is used for big blockbusters as it gives better, brighter pictures. The giant-screen Imax and Omnimax systems use the largest frame and a horizontally moving film.

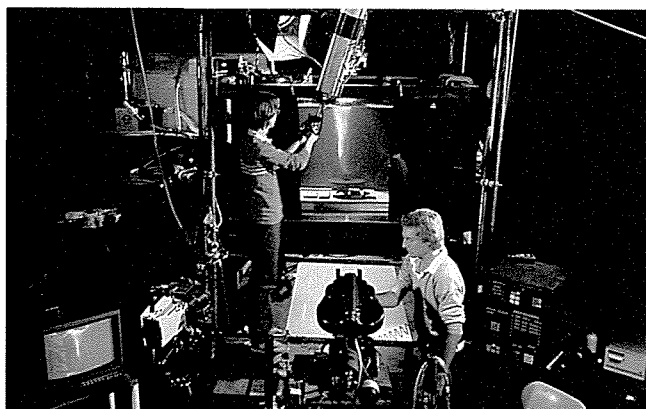
Shooting a scene for the epic comedy The Adventures of Baron Munchausen on location at Almeria in Spain. Even though it is broad daylight, powerful arc lamps are needed to get the scene lit properly.



Special effects are even more realistic – and more dramatic – these days thanks to new technology, including lasers, digital electronics and computers.

are blown up from 35mm to 70mm for showing. However, only the big, city-centre cinemas have the necessary 70mm projectors to show it. If you get the chance to see a 70mm film, you'll notice that the quality is much better.

MGM/FLM Entertainment



from 24 to 48 or 72 times a second – well above the flicker rate that the human eye can detect. The shutter closes before the frame moves on, which prevents any blurring of the projected picture.

One unwanted effect of the shutter movement is to cut down the amount of light reaching the screen. To get around this, modern projectors are fitted with powerful Xenon discharge lamps, which are very efficient light sources.

The standard frame size for most films is 35 mm – literally the width of the film – which has also been adopted for many ordinary still cameras. This gives a reasonably bright image over quite a large

screen and is fairly cheap to use. But the search for large, high-resolution films has led to many variations in screen size and film format.

Wider and wider

One of these variations was Cinerama, where the enormous size of the cinema screen created the illusion that the viewer was right in the action. The Cinerama screen was so large that three cameras had to take separate films, and three projectors had to be used to project them on to the screen. Unfortunately, the joins between the images tended to show like those in a bad wig.

The best-known Cinerama pic-

MOVING PICTURES

ture was probably 2001, A Space Odyssey. This was shot on single lens Cinerama, but has now been transferred to Cinemascope, which needs much less special equipment than Cinerama.

In Cinemascope, a special lens, called an anamorphic lens, is used to squeeze a wide-angle view on to ordinary 35 mm film. When projected at the cinema, another anamorphic lens on the projector spreads the image out again.

Perhaps the best of the wide-screen systems was Todd-AO. This used 70 mm film – twice as wide as standard 35 mm film. In the cinema, Todd-AO produced a wide-screen image twice as wide as it was high. The image was much brighter and could fill the screen better than any 35 mm system could.

Standard 70mm film is still the most popular of all the wide-screen formats and most big-budget films

Elliott Erwitt/Magnum Photos

Just amazing!

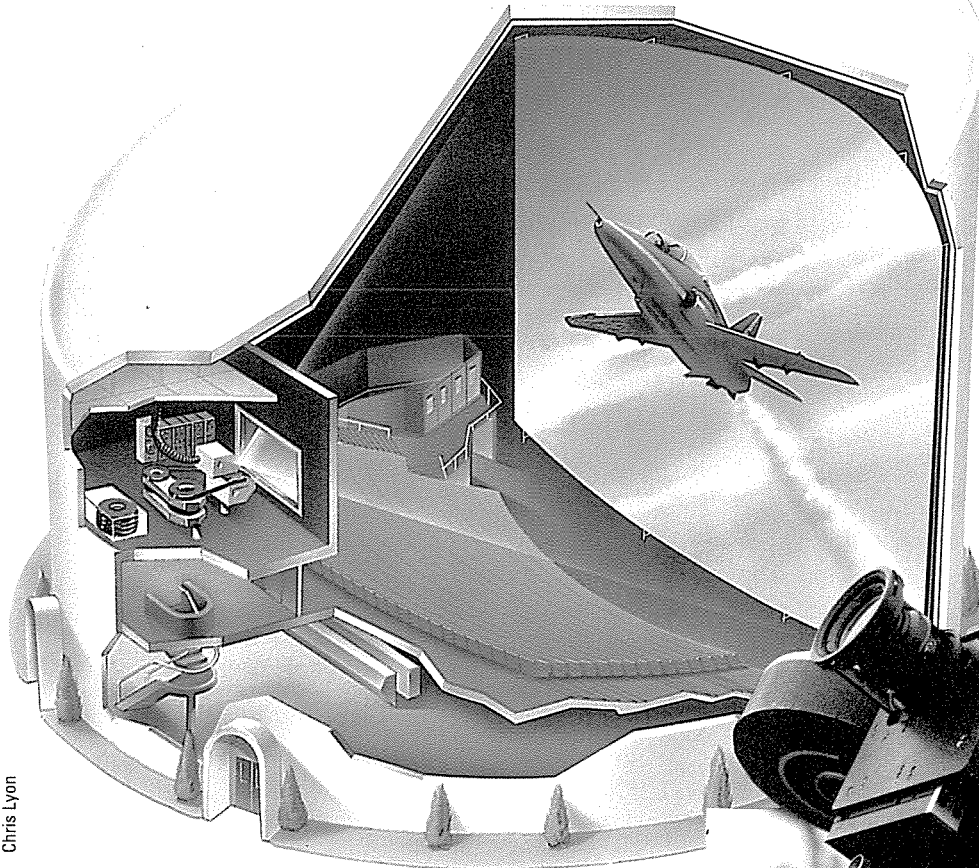
BLOCKBUSTER!

STEVEN SPIELBERG'S FILM E.T.: THE EXTRA-TERRESTRIAL HAS PROBABLY EARNED MORE THAN ANY OTHER FILM. BETWEEN JUNE

1982 AND 1989, IT GROSSED MORE THAN \$700,000,000 WORLD-WIDE.

Paul Raymond





An Omnimax theatre can seat up to 500 people. The audience sit in reclining seats that enable them to look up in comfort at the huge 23 metre screen, which is tilted at an angle of 30 degrees to the horizontal. Omnimax uses 70 mm film, but its image area is a massive 2,665 sq mm – almost two and a half times as big as the 1,072 sq mm image area of the standard-format 70 mm film. Imax theatres hold up to 1,000 seats – and the quality of image in both Imax and Omnimax is unsurpassed.

Roger Scruggs/Imax Systems Corporation

PRINTS FOR DISTRIBUTION



When a movie is shot, the film used in the camera is processed, then a positive is made. This is edited. Then the original negative is edited, the sound is mixed and this version is copied many times to produce the prints that are distributed for showing to the public in cinemas.

An advanced high-definition, giant-screen system is called Imax. Unlike other formats, where the film runs past the shutter from top to bottom, in Imax cameras and projectors the film runs from side to side. Imax cameras use 65 mm film and have the largest frame size ever used in movie cameras. The projectors use special 70 mm copies of it.

The size of each frame is very

large compared with any of the other systems, including standard 70 mm. An Imax film therefore allows a lot of light through to the screen, with excellent quality.

A further development of Imax is called Omnimax. In this system, the image is projected through a special fish-eye lens that spreads it out over a screen that forms a half circle. The screen is 23 metres across and set at an angle of 30 degrees to the horizontal. To see the complete Omnimax picture, you have to lie back on a reclining seat so that you can take it all in.



Faster speeds

The other path to higher resolution is by using faster frame speeds. A system called Showscan takes the large 70 mm format used by Todd-

In Imax and Omnimax cameras, the film moves horizontally instead of vertically. The horizontal reel housings are located to the right of the lens.

AO and runs it past the camera and projector at 60 frames a second instead of 24.

Other experiments are being made, including shooting ordinary 35 mm film at 30 frames a second, to improve picture quality.



Stereo sound

The standard optical sound track is quite wide, so the first stereo pictures had two or four magnetic sound tracks on the side of the film. But adding the magnetic track was difficult and expensive, the magnetic stripe wore as the film passed through the pick-up heads and making prints was a slow process.

So the Dolby Corporation designed an electronic device to take four magnetic tracks and reduce them to two optical ones, the same width as a single optical track. These twin tracks are played back through another Dolby device which decodes the two tracks, producing realistic stereo.

Dolby also produce a noise reduction system. Low-level sounds are boosted during recording and reduced on playback. As a result, the original sounds are reproduced normally, but recording hiss is greatly reduced in the process.



FACTORIES OF THE FOREST

AXING HARDWOODS

TAPPING RUBBER

HYDROELECTRIC POWER

MUCH VALUABLE TIMBER IS found in the rain forests. Woods such as mahogany and greenheart from South America, and teak from South-East Asia have been used by industrialized countries for furniture and building.

These trees are all hardwoods — they have solid, strong, good quality wood with an interesting grain. Because of their grain, many rain forest trees are cut into thin slices

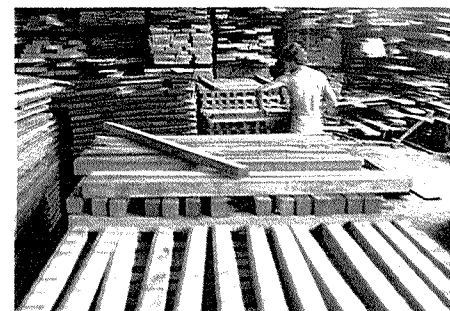
and made into veneers.

Logging is one of the main causes of the destruction of the rain forests: it devastates 5 million hectares every year. In industrialized countries, demand for hardwoods is growing and countries with rain forests obviously want to sell their wood to make money.

One rain forest tree can bring in up to \$1,000 in much needed foreign currency. By the time it has been turned into parquet floors, yacht

The road ahead for native Indians is a bleak one when highways in rain forests plough right through their homelands and hunting areas.

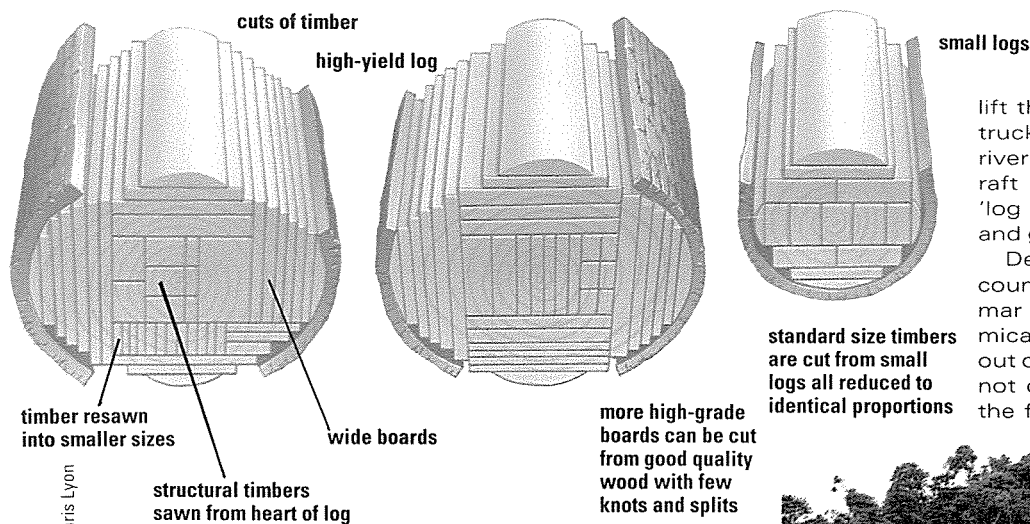
Hardwoods, such as teak, ramin and sapele, are in great demand for furniture because of their attractive close grain. Most of the teak has been cut.



A Venzagio/Magnum

Tony Morrison/South American Pictures





lift the heavy logs on to transporter trucks or lower them into rivers. In a river, the logs are tied together in a raft and towed downstream to a 'log pond', where they are sorted and graded, ready for export.

Despite modern technology, countries such as India and Myanmar (Burma) still find it more economical to use elephants to pull logs out of the rain forests. Elephants can not only move more easily through the forest and do less damage, but

Vaughan Fleming/Science Photo Library

planking and veneers for furniture, its value may have gone up to \$17,000.

If industrialized countries used less hardwood, this would bring prices down and would be a major step towards saving the remaining rain forests. In Thailand the total area of tropical forest shrank from 70 per cent to 18 per cent of the country between 1945–89. All logging is now banned in Thailand.

Suitable trees

It has always been difficult to get the valuable timber out of the rain forests. Groups of one species do not grow together, as they do in pine forests, but are scattered throughout the forest. In an area the size of two soccer pitches there may be only three suitable trees. When these trees are chopped down, they damage or destroy the trees around them — rather like a factory chimney crashing across a housing estate.

Boards are sawn from one side of the log at a time. When all four sides have been 'worked', beams are cut from the centre.

One minute is all it takes for a machine to reduce a giant tree to woodchips, which are used to make particle and chip board.



short-term profits than in planning for future forests.

Apart from the distribution of trees in the forest, other problems for the loggers include the heat, humidity and the abundance of insects. The trees are difficult to fell not only because the wood is hard, but also because many have wide-spreading buttresses, which may be as high as 10 metres above the ground. On a tree like this, loggers may have to build a platform high off the ground in order to reach the straight trunk.

Timber!

After chainsaws have cut down the trees and lopped off the branches, huge cranes, bulldozers and caterpillar tractors move the logs to the collection point. Here, cranes

one elephant can do the work of four bulldozers.

About three-quarters of the trees felled in rain forests are exported as logs, because few developing countries have the sawmills necessary to deal with more than a small fraction of their annual log harvest.

Processed logs

The developing countries would get at least five times as much money from each tree if they 'processed' the logs (into veneers, for example) before export.

For most countries, the income from exporting mainly unprocessed wood is eaten up by the need to import sawn timber, plywood and paper. Nigeria was once a major timber exporter. It is now on the verge of losing all its forests and

Elephants are preferred to bulldozers to clear the jungle in many countries. They are more easily available and one animal can do the work of four machines.

Mangrove swamps along the estuaries of the Amazon have adapted to the salt content of the water. They provide valuable firewood.



L C Marigo/Bruce Coleman Ltd

In one Malaysian forest, although only ten per cent of the trees were cut for timber, more than half were destroyed or severely damaged by bulldozers or rot, which sets in once branches are broken off the trees. When the trees have been cut down, new trees are rarely planted to take their place, as most logging companies are more interested in



Latex – a natural resource – is tapped by scoring the bark of a rubber tree. The milky sap collects in a cup.

old are 'tapped' for the milky sap. The latex comes from a layer of tiny tubes spiralling up the tree just underneath the outer bark. Latex contains about 30 per cent rubber by weight. To tap the latex, a sliver of bark is cut at an angle of about 30° to the horizontal so as to cut through many latex tubes.

A cup is fixed to the tree at the bottom of the cut, to collect the latex as it oozes out. After two or three hours, the flow stops and the latex is ready for collection. The next time the tree is tapped, a cut is made just below the first one and so on down the tree. The bark gradually heals and the tree can be tapped again and again.

A more modern technique uses several small holes instead of one

Excavators clear the way for road building in the Amazon. The 759 km road (inset right) that links Manaus in Brazil to Boa Vista in Venezuela is only partially paved.

imports more than 100 times as much wood as it exports.

Rubber is made from a milky sap called latex, which is produced by certain tropical trees. Rubber was originally harvested from wild trees in the Brazilian jungles. After a while, however, the wild trees were over-tapped and rubber production fell.

Sap-tapping

Spreading industrialization greatly increased the worldwide demand for raw rubber. In 1876, Henry Wickham smuggled 70,000 seeds of the most promising latex producing tree out of Brazil to England – but only four per cent grew. The seedlings were sent to Sri Lanka and Malaysia to start the rubber industry there. There are now an estimated three billion rubber trees in South-East Asia. Malaysia produces nearly half the world's rubber – exports earned nearly \$4.5 billion in 1979.

Rubber trees from six to 30 years

Dr Morley Read/Science Photo Library



Tony Morrison/South American Pictures

Just amazing!

FILL HER UP

THE SAP FROM THE COPAIBA TREE IN THE AMAZON CAN BE USED TO POWER A DIESEL TRUCK. IT IS ALMOST IDENTICAL TO DIESEL FUEL – IN AN EMERGENCY, IT CAN BE POURED INTO THE FUEL TANK.



Paul Raymond

large cut. With this method, the bark has to be treated chemically to make sure enough latex flows out of the cut. Chemicals can also be painted on the trunk of the rubber tree to increase yield.

Formerly, the latex was converted to rubber sheets, which were exported in bales weighing over 100 kg each. A more modern method, which is faster and more economical, is to turn the latex into granules. It is chopped, minced or mixed with a crumbling agent (such as castor oil), then passed between rollers to break it up into small pieces.

The granules can be washed and dried in just a few hours. The dried

rubber is shaped into bales, weighing 33 kg, these are wrapped in polythene before being shipped to the makers of rubber products.

The energy potential of the rivers in the rain forests is gigantic. Brazil pays over \$12 million each day to import oil, so it has every reason to develop its own hydroelectric energy.

The first rain forest dam was completed in Surinam (just north of Brazil) in 1964. Around 150,000



hectares of rain forest were flooded to create a huge reservoir, but as the trees decomposed they produced stinking fumes of hydrogen sulphide gas. For two years, workers at the dam had to wear gas masks.

Cooling problem

The jungle vegetation also made the water acidic and this corroded the dam's expensive cooling system. A similar problem at the Curua Una Dam in the Amazon involved replacing the steel casings of both turbines at a cost of over \$5 million.

At Jupai, a dam on the Parana river just outside the Amazon re-



gion, the sheer weight of the mass of weeds (such as water hyacinths) growing on the surface of the lake has snapped steel cables.

Jungle highways

Another major effect of building dams, reservoirs and roads through the jungle has been to uproot the Indians who lived there. Indian lands have been used for logging and mining and settlers have moved in to farm the land. In the 1500s, up to nine million Indians lived in the Amazon rain forests. By the 1990's, less than 200,000 Indians survive.

1970 and built by 1974. It is made of hard earth and is not paved, unlike some of the newer roads, such as the Belem-to-Brasilia highway.

The speed of building the road was due to massive international aid and a large amount of technical assistance, such as satellite reconnaissance techniques, heavy earth-moving equipment and helicopters.

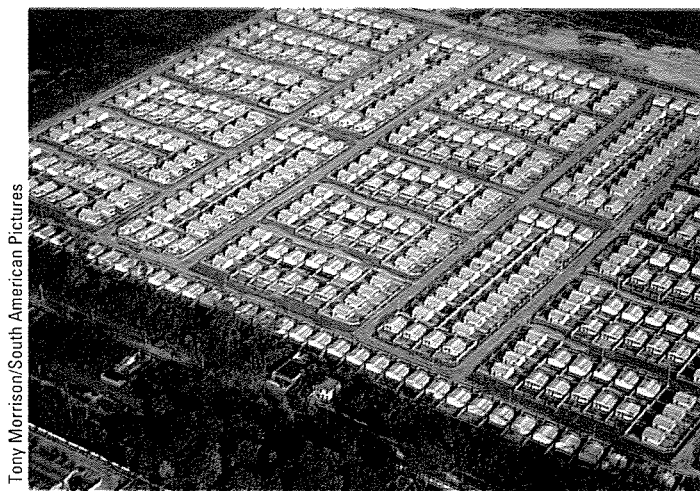
A major project, Project Radam, was also invaluable to the speed of construction. It mapped and surveyed the entire Amazon region from aerial photographs. Detailed

REVENGE OF THE JUNGLE

In the 1960s, an American, Daniel K. Ludwig (said at the time to be the richest man in the world), bought a vast area of rain forest in Brazil for about \$800 million. He cleared all the native trees and Indians to grow a huge plantation of fast-growing foreign trees, such as eucalyptus and pines. But the trees did not flourish, because the jungle soil did not have enough time to regenerate between the quick plantings. Ludwig abandoned the project in 1982, having lost nearly \$75 million.

A housing
development in the rain forest provides extra accommodation for the overcrowded town of Belem in Brazil.

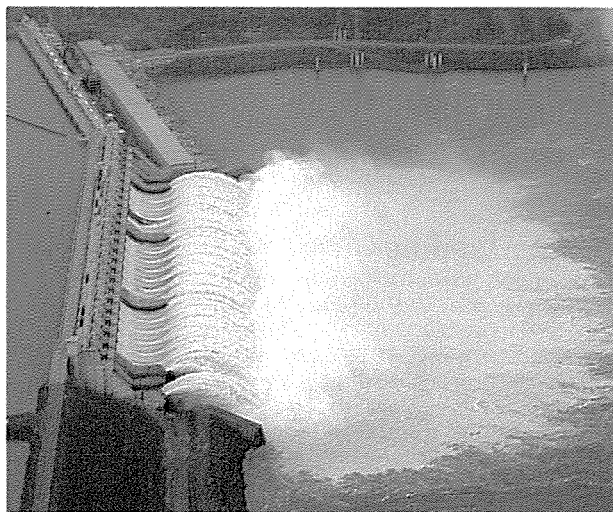
aerial maps of the geology, waterways, forestry, vegetation and geography of the Amazon were prepared in less than a year. This would have taken ordinary surveying expeditions 25 years to complete. Aerial surveys can also locate ore deposits by detecting magnetic variations.



Tony Morrison/South American Pictures

In the 1960s, Brazil decided to build a system of pioneer roads across the Amazon jungle to open up the land. The 5,000 km Trans-Amazonian highway, which runs from north-eastern Brazil westward to Peru, is a major part of this road system. The road was started in

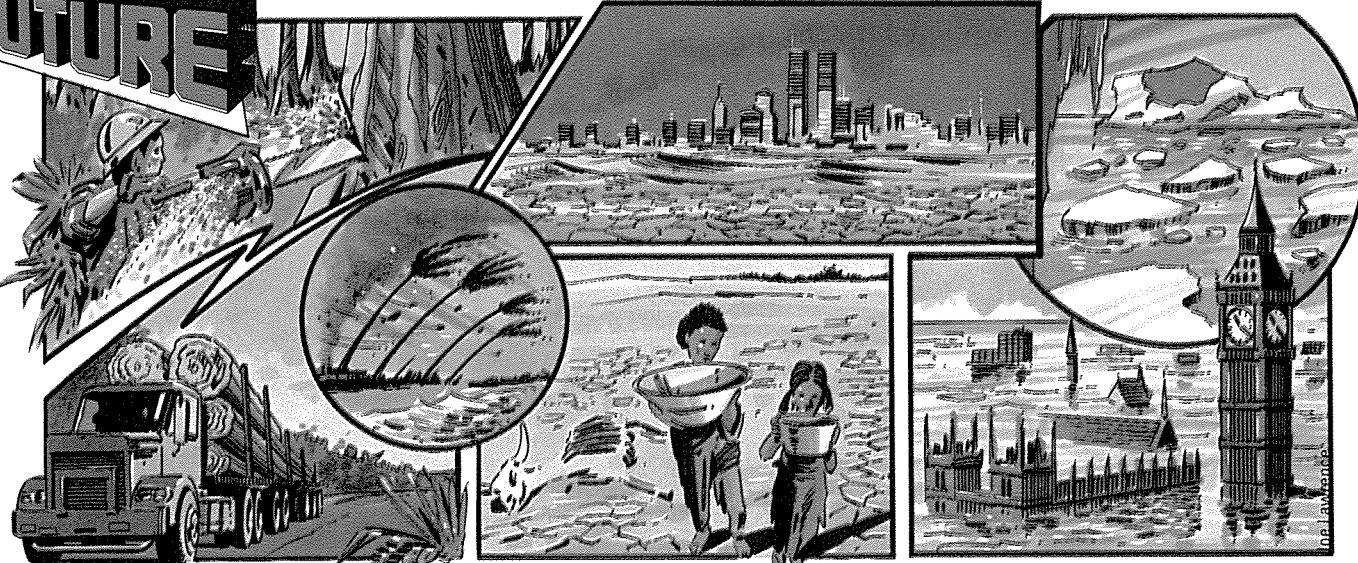
The Tucuruí dam in Brazil is 2 km long; the reservoir flooded 200,000 hectares of jungle. During construction, four refrigeration plants were built to keep the concrete at the right temperature.



Michael Macintyre/Hutchison Library

INTO THE FUTURE

GLOBAL WARMING



▲ If the wholesale destruction of the rain forests continues, the shift in the world's weather will cause a global catastrophe because much less rain will fall.

▲ Global warming and the resulting drought will turn the major grain-producing areas of the world into deserts. Millions will starve.

▲ The polar ice caps will melt, raising the sea level to the point where most of the world's major cities built near the mouths of rivers could be under water.





Christopher Sainsbury/Orpix

SURVIVAL IN THE JUNGLE has been the mother of chemical invention for plants. Over millions of years plants have experimented to produce a range of unpleasant and poisonous chemicals, to deter grazers and pests, and attractive ones to lure pollinators.

About one-third of modern drugs and medicines are made from plant products. Most of the rest were originally made from plants, but are now produced synthetically. Around 400 modern medicines are 'plant drugs'. Manufacturing them represents an industry worth hundreds of millions of pounds yearly –

and many of the plants are from the jungle.

One of the basic groups of plant chemicals used in modern medicine is the alkaloids. It includes caffeine (the 'pick-me-up' in coffee), quinine (a cure for malaria) and morphine (a painkiller), all of which affect the brain and nervous system.

Heart failure

Another group is the glycosides, found in foxgloves, cascara and senna; these mainly affect the heart and are used for heart failure and other cardiac problems.

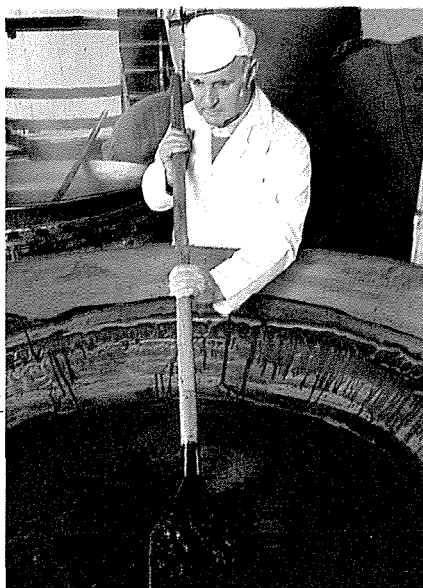
Nearly 2,000 jungle plants have been identified as possible cancer

Medicinal plants are found throughout the jungle. The leaves of this Indonesian shrub are mashed and applied to cuts and wounds to prevent infection.

cures. The American mandrake, the bloodroot, one of the crotons and a type of jacaranda are all used by jungle people to treat cancerous growths.

A chemical extracted from the rosy periwinkle – vinblastine, is now used as a treatment for leukemia and helps to keep four out of five children with the disease alive.

Another rosy periwinkle extract – vincristine – is used to treat the type

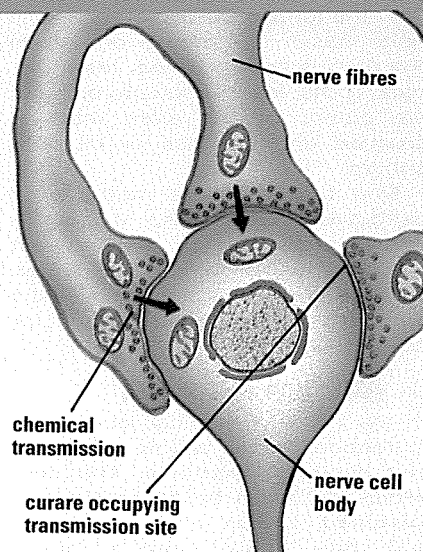


William Ransom & Son plc

CURARE – AN OLD DRUG WITH MODERN USES

Curare works by preventing nerve messages from 'jumping' from the end of the nerve to the muscle beyond, so that the muscle is not stimulated to contract. It does this by blocking the action of a chemical messenger called acetylcholine, which would normally cross the microscopic gap between nerve and muscle and slot into receptor sites on the muscle. Curare occupies the receptor sites instead, blocking the chemical messenger without stimulating the muscle.

Concentrated plant extract collected from the Cocillana bark of the Guarea rusbyi tree, found in the rain forests of Haiti and Bolivia, is used in a cough preparation.



John Houghton





The germ-free chamber (far left) is home to a child suffering from cancer. The drug treatment, known as chemotherapy, that the child is undergoing involves a chemical called vinblastine, an extract of the rosy periwinkle (left).

Neyla Freeman/Bruce Coleman Ltd

Analysis of medicinal plant extracts can be rapidly achieved in the laboratory using equipment such as this high-pressure liquid chromatograph; this identifies chemicals by the rate at which they move through the liquid.

of cancer known as Hodgkin's disease and four out of five people with this disease recover for months or years. There are, in fact, more than 70 alkaloid substances in this little plant and research is continuing to find the ones that will be useful to medicine.

Curare was used by the jungle people of the Amazon and Orinoco regions to poison the tips of their bamboo arrows. There are several different sorts of curare. One type, tubocurare, is a powerful muscle relaxer and is used in operations, because it enables the surgeon to move around the body's organs more easily. It is also a treatment for conditions such as spastic paralysis, multiple sclerosis and Parkinson's disease.

Quinine revival

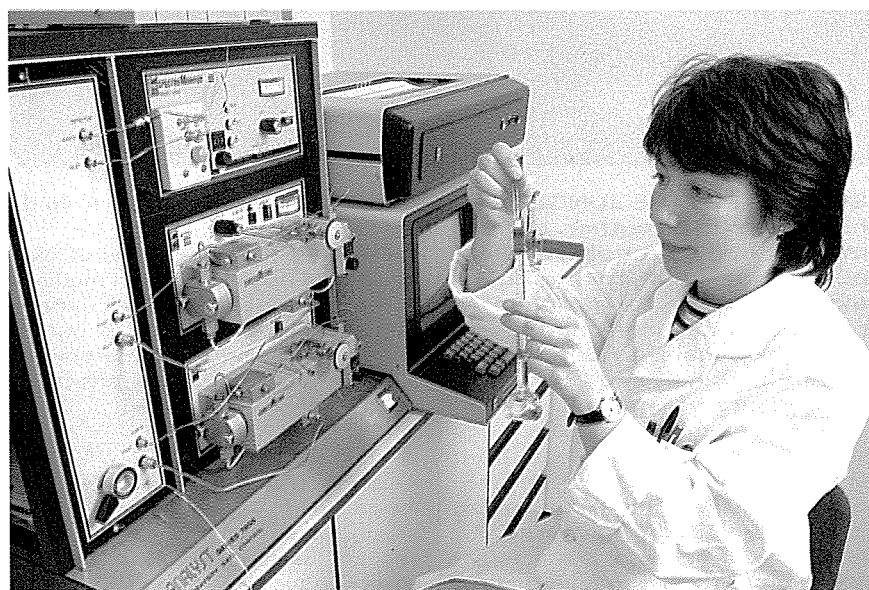
Quinine is made from the bark of the chinchona tree, which grows in the jungles of South America and Indonesia. Once the only treatment against malaria, it was gradually replaced by synthetic drugs. Since 1984, however, it has enjoyed a large-scale revival as the microscopic organisms, which cause the disease, have become resistant to many of the synthetic drugs.

In the jungle, plant preparation is quite basic. Depending on where the drug is concentrated, the stem, bark, roots, leaves, flowers or fruits are eaten; or the plant may be crushed and its juice or oil consumed.

One of the oldest methods of extraction is to make a tea by 'infusing' (steeping) the relevant part of the plant in boiling water. Infusion may also be achieved by letting it soak in cold water for several days.

Modern research

In the modern medical laboratory, extraction is by various solvents and chemical reactions. The chemicals can then be separated and identified using chromatography and then 'copied' into a 'purer'



William Ransom & Son plc

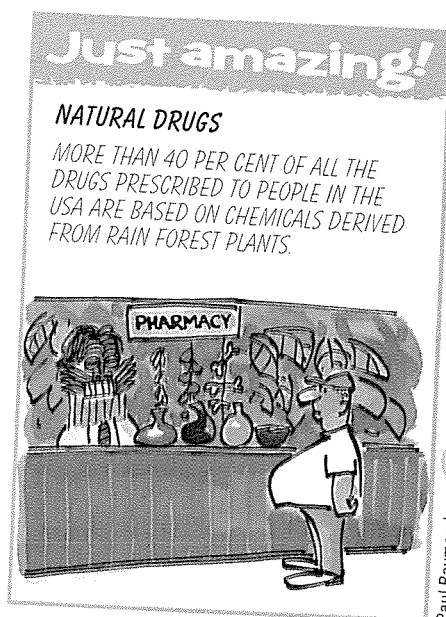
form, using laboratory chemical reactions.

Although modern techniques produce a drug with less notable side-effects, some traditional cures only work 'straight from the plant'. This is because their ability to cure comes from the various chemicals in the plant working together, not from the action of one chemical on its own.

Medicinal plants

There are literally thousands of jungle plants with medicinal uses. The snakeroot plant from Indian forests, for example, has been taken to help overcome insomnia and is also used as a sedative.

Ipecacuanha, a Brazilian jungle shrub, contains a drug that causes vomiting — useful in cases of poisoning. Modern man has, however, largely left such medicinal secrets to the native peoples.



Paul Raymond

BIOTECHNOLOGY

FARMERS HAVE CROSS-BRED their crops to try and increase yields and eradicate disease throughout history. Such trial and error methods, however, take years and the results are always uncertain. Plant clones, on the other hand, are identical to the parent and may be reproduced endlessly.

Simply by taking a leaf or shoot cutting from a plant and nurturing a new plant from it, you are reproducing a single plant that is genetically identical to its parent. Although effective, this method is not very efficient for large-scale reproduction.

One alternative, used in the mass propagation of the jojoba plant, is the shoot tip method. Tiny shoots are cut from the parent plant and grown in a sterile jelly rich in nutrients. Once stimulated to bud in this way, the little plants are rooted.

Forming a callus

In some cases, however, the normal methods of tissue culture do not work. Thus, to clone the oil palm, for example, it is necessary to produce an intermediate clump of cells called a callus. Root tissue from the desired plant is placed in a nutrient-rich jelly and stimulated by growth hormones to form the disorganized mass of cells known as a callus. Once formed, a callus can be subdivided in the laboratory almost indefinitely and nurtured to produce large numbers of embryo plants, or clones, each genetically identical to



Charlotte Raymond/SPL

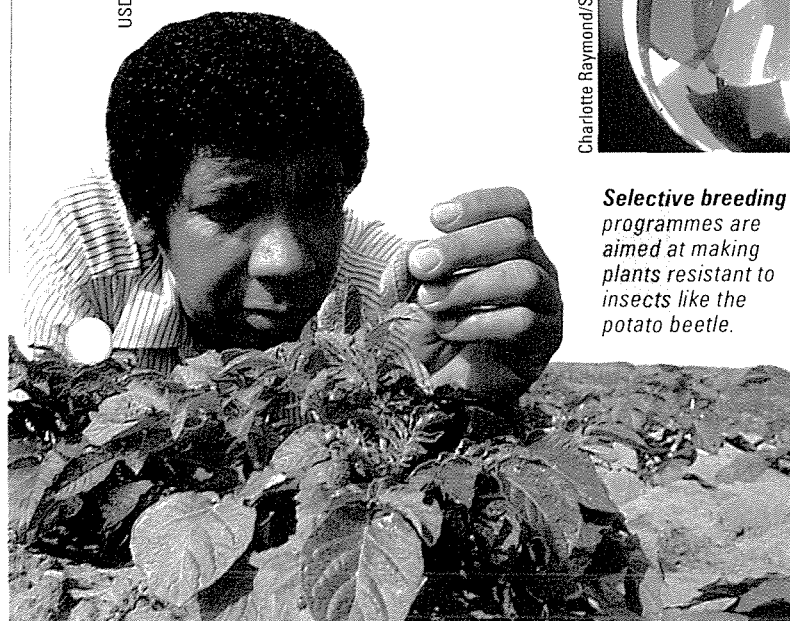
USDA/ARS

Selective breeding programmes are aimed at making plants resistant to insects like the potato beetle.

Seedlings, developed from tissue cultures, growing in a sterile growth medium in test tubes. This technique enables rapid and prolific propagation and is used to make crops that are resistant to virus infection and disease.

the parent plant.

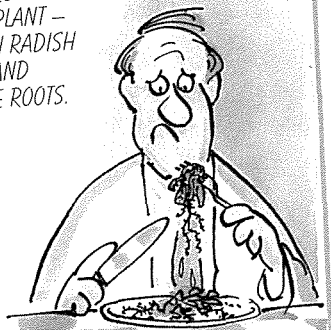
Cloning is very important in farming and forestry where the best plants can be reproduced as required. Trees take years to grow, but only minutes to cut down. In the laboratory, however, hundreds of seedlings can be produced very quickly. Furthermore, the trees grown from them will have the appropriately desired qualities such as height, straightness and fewest branches. Plantations 'con-



Just amazing!

CABBISH OR RADAGE?

AN ATTEMPT TO CROSS CABBAGE AND RADISH PLANTS TO PRODUCE A HYBRID WITH CABBAGE LEAVES AND RADISH ROOTS RESULTED IN A FERTILE PLANT — BUT WITH RADISH LEAVES AND CABBAGE ROOTS.



Paul Raymond

structed' from cloned plants typically give a 20–30 per cent better performance than comparable uncloned plantations.

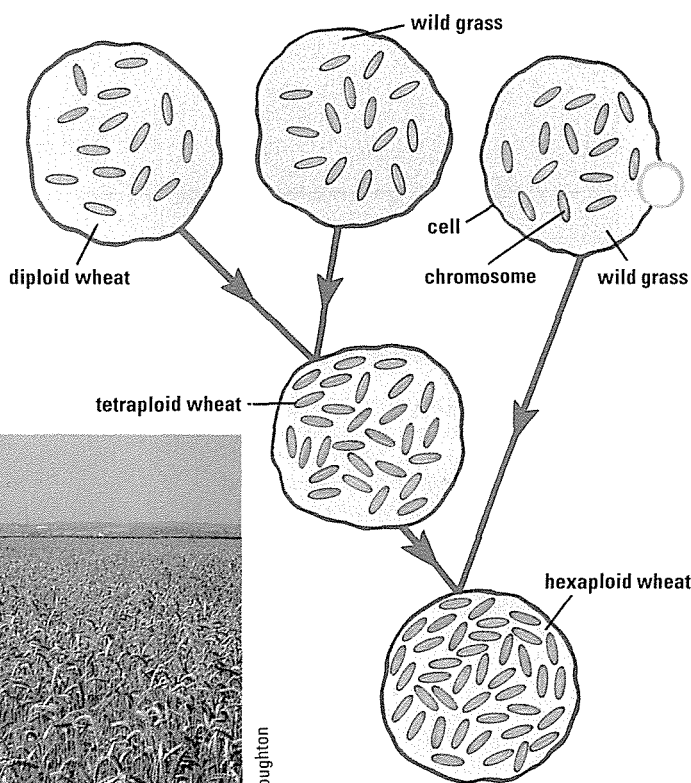
Cloning methods have also been put to good use for the production of certain drugs. Instead of allowing plant tissue to develop into plants, cells from the Madagascar periwinkle, for example, can be maintained in flasks where they produce vincristine — a chemical that is used in the treatment of leukaemia.

Manipulating genes

Beyond cloning is the area of genetic engineering. Scientists are able to introduce specific new characteristics into plants by manipulating the appropriate gene or genes into the plant's chromosomes while they are being cultured.

First, the new gene is isolated from the DNA (deoxyribonucleic acid) of the donor species and introduced into the parent plant cells, which are then grown into adult plants. The manipulated plants are known as 'transgenic' plants. Such techniques have successfully produced fields of rye

Cross-breeding has created harder types of wheat that are far easier to harvest (below). The ability of many plants to double or treble the number of their chromosomes is known as **polyploidy**. Crossing a primitive, diploid, wheat with a wild grass produces an improved, tetraploid, type. Crossing this again produces even better, hexaploid, wheat.



ZEFA

John Houghton

that are resistant to damage by certain toxic chemicals, and tobacco plants that are resistant to insect pests, virus and disease.

In spite of Man's success as creator of new, improved plants, nature has in fact been experimenting genetically for a lot longer. An unusual trait of plant reproduction is the ability of many plants to double or even treble the number of chromosomes without adverse effect. Having multiple sets of chromosomes is known as polyploidy and is achieved either by the plant hybridizing with itself or, less commonly, with another plant species, with all the chromosomes being retained.

When polyploidy occurs in Man or other animals the foetus usually dies because increasing the number

of chromosomes in the cell makes cell division impossible.

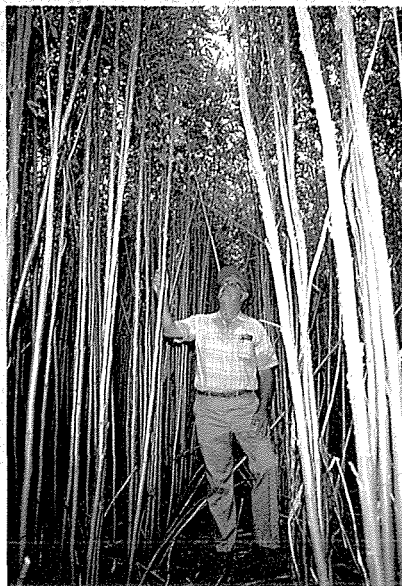
In plants, on the other hand, polyploidy occurs naturally. Around 40 per cent of all plants are either polyploid or of polyploid origin. The offspring are thus genetically iso-



Sinclair Stammers/SPL

THE FOREST SAVER

Kenaf is a plant that is currently being grown in the USA for its potential as high quality newsprint. Since the 1940s kenaf has been selectively bred to produce a higher ratio of the usable outer bark. In the 60s and 70s more work has gone into producing a plant that is tolerant of a crippling organism, root knot nematode, that is found in the light, sandy soils of the southern USA. Such varieties are now being successfully farmed. One project in Texas involves planting kenaf on 40,000 acres for a papermill which can produce 225,000 tonnes of newsprint a year. The paper is brighter than paper made from wood pulp. It does not yellow as quickly and retains ink far better.



Anti-cancer drugs, vinblastine and vincristine, are produced from tissue culture of the Madagascar Periwinkle.

lated from the parent species.

Fusion hybrid is the name given to new plants, normally close relatives such as cabbage and Chinese cabbage, which are created artificially. In this technique cells are isolated and 'protoplasts' — a kind of cellular stew — made from them by removing the cell walls. The protoplasts from two species are then fused in an attempt to create a hybrid with the best characteristics from each parent.

USDA/ARS



GENETIC ENGINEERING

MAKING INSULIN

TRANSGENIC ANIMALS

A HUMAN GENE MAP

THE UNDERSTANDING OF DNA has opened up a whole new branch of technology called genetic engineering. Like much of modern science, it offers a choice between dream and nightmare, depending on how the techniques are used.

Every gene works by acting as the template or pattern for the formation of a protein. A lot of foods and drugs as well as many industrial products are made of protein, so the discovery of DNA presented the possibility of using genetic material for manufacturing purposes.

A drug called human insulin was one of the first substances that anybody thought of making through genetic engineering. The first step was to locate the human gene responsible for insulin production and then find a way that it could produce insulin away from the human body. The easiest route was to fit the gene in a simple bacteria found in the human stomach called *Escherichia coli*.

This organism was chosen because it contains separate rings of

DNA (called plasmids) that can easily be removed from the cell. The DNA rings are snipped open and the human insulin gene 'glued' into the ring using enzymes. When the modified DNA ring is replaced in the *E. coli* bacterium, it produces insulin using the information carried in the insulin gene.

To encourage *E. coli* to reproduce as fast as possible, the modified bacteria are placed in a bioreactor. This is a large container of warm water containing plenty of nutrients, with air bubbling through it so that *E. coli* can breathe.

New drug source

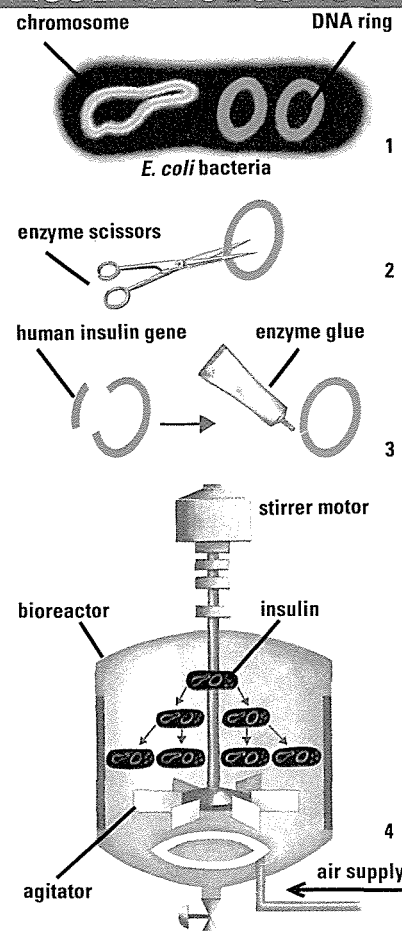
Several other drugs like Human Growth Factor and an agricultural hormone called BST are already being made using similar types of genetically-engineered bacteria. The splitting apart of the ring of DNA, to be recombined with a piece of DNA from another organism is known as recombinant DNA technology. In the future, this will almost certainly become a source of many more drugs.

Bacteria can be modified to digest things like grass or even oil which cannot be digested by humans. The

protein will be extracted, shaped and flavoured so that it resembles meat.

Scientists can also transfer genes from one animal species to another. The desired gene is first separated from the rest of the chromosomes and cloned in exactly the way described above for insulin. DNA can be obtained from any tissue or cell

INSULIN PRODUCTION



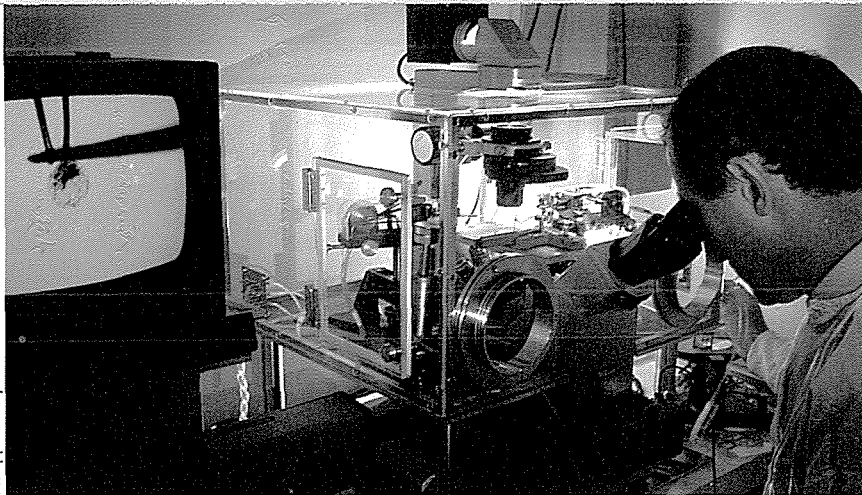
A bacterium from the human intestine called *E. coli* (1) is the workhorse of genetic engineering because it contains separate rings of DNA which are easy to remove. To make human insulin, the DNA rings are opened up (2) and the gene for making human insulin is fitted into the ring using a chemical – an enzyme – called ligase (3). The modified DNA ring is then replaced in the cell of *E. coli* and fed into a bioreactor (4). Each cell produces some insulin and when the bioreactor is full, the bacteria are broken open chemically and the insulin is extracted. Insulin regulates the amount of sugar in the blood. Without it, diabetics die.

Large quantities of genetically engineered bacteria are encouraged to reproduce in fermentation units.

Caroline Brodie

Alexander Tsiras/SPL





TV cameras take the image from a microscope and feed it onto a screen, allowing genes to be microinjected.

type for this purpose (often white blood cells are used). Copies of the DNA are produced in bacterial cultures, the desired gene is purified and then 'micro injected' into the nucleus of an egg of the other species using a special syringe.

Animals that develop from these eggs with microinjected genes are known as transgenic animals. The first such animals were mice bred for use in laboratory experiments. These mice were given the growth hormone gene of a rat and some of them grew to twice normal size!

Recently, a human gene responsible for the production of a part of human blood known as Factor IX has been transferred into some sheep eggs. Factor IX is the part of human blood which makes it clot after a cut. Somebody who does not produce this part of blood for themselves can easily bleed to

death, so they must receive Factor IX regularly.

The transgenic sheep have the Factor IX gene in every cell and produce large quantities of Factor IX in their milk. This is very convenient because it means that the Factor IX can be extracted from the milk.

One of the most promising areas of cancer research at the moment is to take some of the natural antibodies from the patient's bloodstream and grow large quantities of them in the laboratory. These are injected back into the patient in the hope that the extra antibodies will beat the cancer.

To help them study this process, the researchers are using a bacteria to mark the nucleus of the antibody cells.

Human genes

In America, the largest genetic engineering programme of all time has already begun. The aim of the programme is to produce a map of all 80,000 or so human genes.

Such a map is known as the human genome and this project will

Just amazing!

CHAIN OF COMMAND

IF ALL THE 46 TIGHTLY COILED CHROMOSOMES IN A HUMAN CELL WERE UNWOUND AND PUT TOGETHER END TO END, THEY WOULD STRETCH TO 1 METRE.



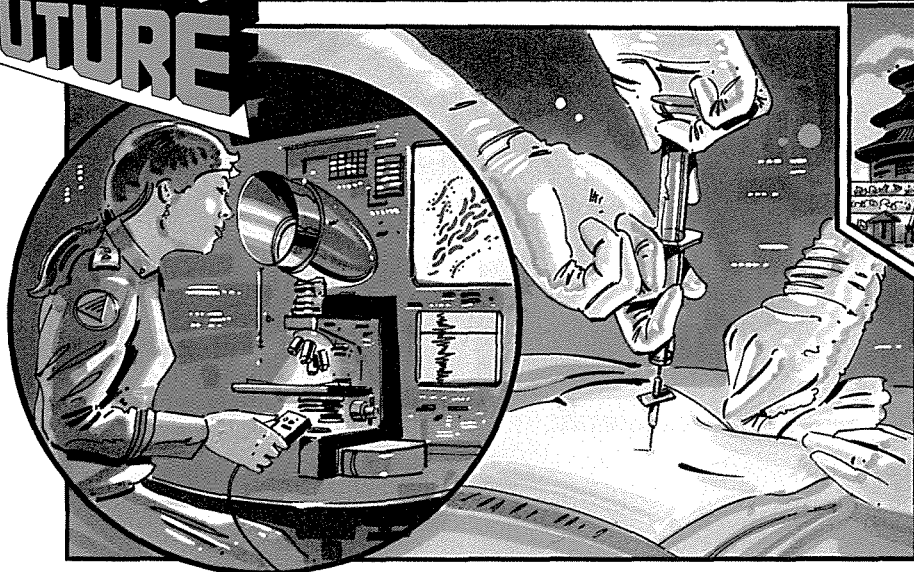
Paul Raymond

cost more than putting a man on the moon. But many scientists are worried about this sort of research. It could help scientists to study and cure genetic diseases but the same knowledge could also be used to engineer different breeds of humans. For example somebody could decide to create a 'genetic soldier'. He would be small and very powerful but pitiless and 'programmed' to obey orders without fear or doubt.

At the moment, few countries have laws against this type of research. However, the European Research Council have advised genetic researchers that introducing 'alien' genes into the egg and sperm cells of human beings is quite unacceptable. If this is permitted to ever happen, it would permanently alter the pool of human genes.

INTO THE FUTURE

GENE GENIUS – A THREAT OR A PROMISE



▲ The human body has no defence against genetically-engineered viruses, so there will be a well-trained genetic police force to control laboratories and hospitals.

▲ Leukaemia caused by genetically-defective bone marrow could be cured by extracting the bone marrow, adding the normal gene, then replacing it.



▲ Lactose is a component of milk that cannot be digested by many people in the Far East. A gene will be modified to produce lactose-free milk.

Lawrence

SPLITTING SECONDS

Star trails over the Himalayas, captured by time exposure photography.

- TIMEKEEPING
- ATOMIC CLOCKS
- THE WORLD'S TIME

Spectrum Colour Library

THE EARTH WAS MANKIND'S first clock. The time our planet takes to rotate once on its axis – approximately 24 hours – gives us the length of the day. The time it takes to travel around the Sun gives us the year.

But the Earth is a poor timekeeper by modern scientific standards. We now take our time from the vibrations of atoms in super-precise atomic clocks.

○ The time of day

A few hundred million years ago there were 400 days in the year. Since the time that the Earth takes to orbit the Sun does not change, this means that the day was then about 22 hours long. One piece of evidence for this comes from fossil corals that show patterns of daily and yearly growth. There is a steady long-term slowing of the Earth's rotation, caused by the drag of the tides. As a result, the day is getting longer – apparently by about 1½ milliseconds per century.

In the short term, the Earth's rotation rate slows down and speeds up by as much as one millisecond (one

Earth Rotation time is measured by the Satellite Laser Ranger at the Royal Greenwich Observatory in Sussex, England, as part of a programme involving 30 stations around the world. The distances to special satellites in stable orbits, as measured by the reflected laser pulses, vary if the Earth's rate of rotation changes.

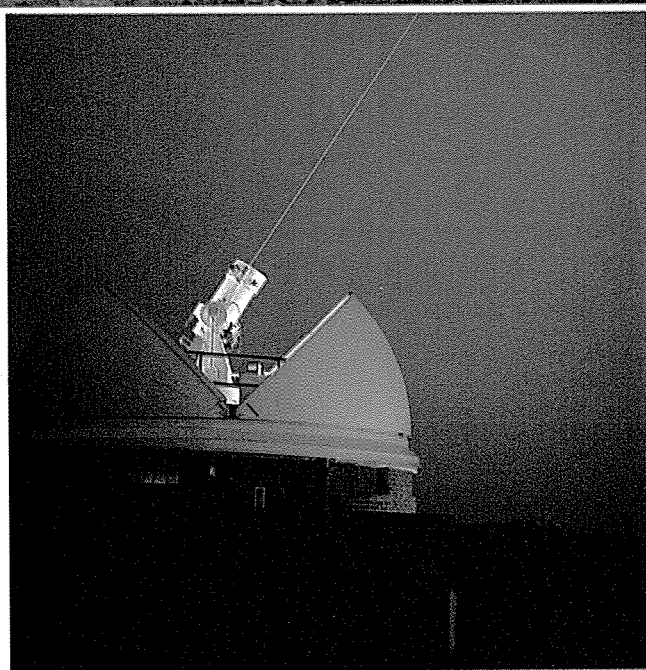
thousandth of a second) from day to day. These changes are random and unpredictable, caused by such factors as movements in the Earth core and changes in the circulation of the atmosphere.

The measurement of time by clocks has improved dramatically in the 20th century. Until the 1930s the most accurate clocks used pen-

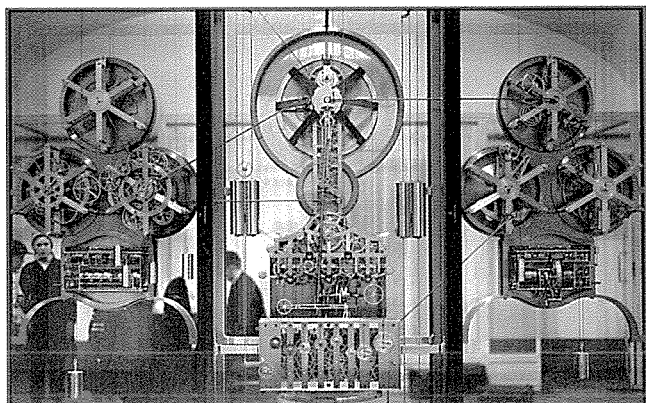
dulum – a weight swinging on the end of a cord or rod. The best pendulum clocks can measure time to an accuracy of a millisecond per day.

The pendulum clock was superseded by the quartz crystal clock, in which a vibrating quartz crystal is used to regulate the rate of thousands of electrical pulses produced every second by an electronic circuit called an oscillator. Another circuit counts the number of pulses required to make a certain fraction of a second, and then sends a single pulse to update the clock's digital display by this amount.

The complicated electronic circuits needed to count the electrical pulses have been squeezed into microchips, and many wristwatches now use quartz crystals. The best



D A Calvert/Royal Greenwich Observatory

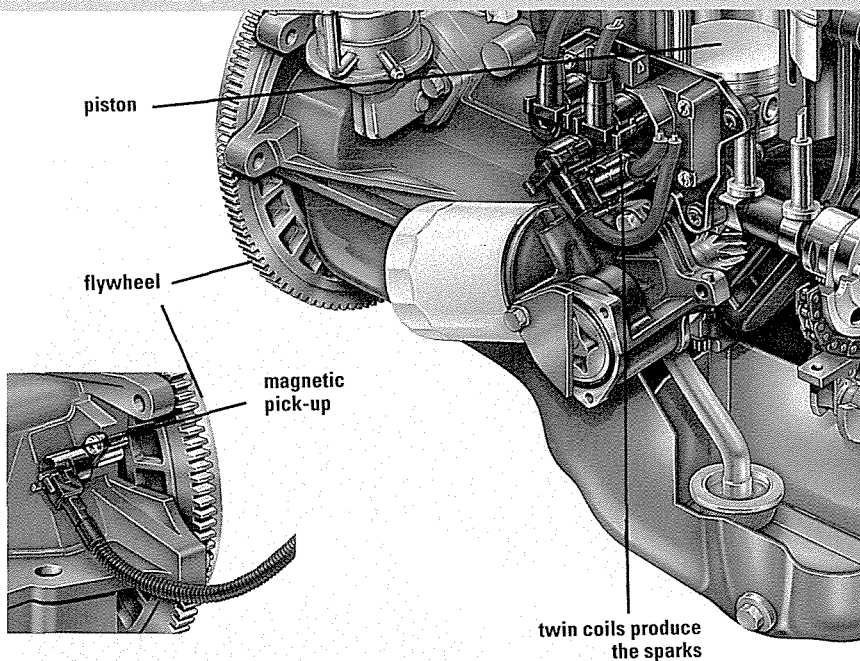


The Olsen Clock has the most accurate and complicated clockwork in the world. Built in Copenhagen Town Hall, it is made up of more than 14,000 parts.



AUE/The Danish Tourist Board

TIMING THE SPARKS



In petrol engines, the ignition system has to deliver a spark up to 6,000 times every minute – each spark timed precisely to coincide with the moment that one of the pistons in the engine comes to the top of its stroke. A mechanical distributor is normally used to do this job. But like all mechanical devices it is subject to wear and tear.

Some modern cars do away with the distributor – and its disadvantages.

Instead a magnetic pick-up creates a signal that changes as the engine runs faster. This signal, plus information on engine temperature and throttle opening, is fed into an electronic processor, which triggers the spark at exactly the right moment in each cylinder.

About 80 per cent of breakdowns are caused by ignition and distributor problems, most of which will be eliminated by electronic systems.

quartz clocks, used in scientific laboratories can keep time to within one ten thousandth of a second in a day.

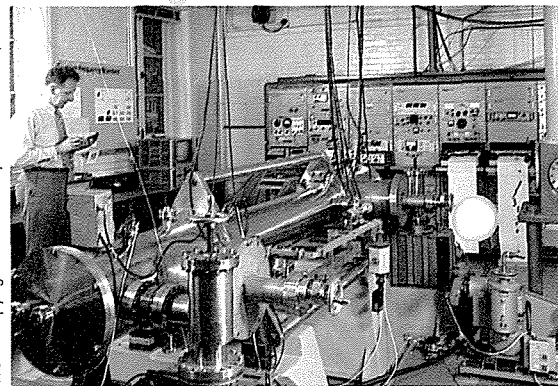
The most accurate timekeepers of all are atomic clocks, which are large, complex, scientific instruments. The caesium-beam clock

rotate once, as calculated at the International Time Bureau in Paris from worldwide observations.

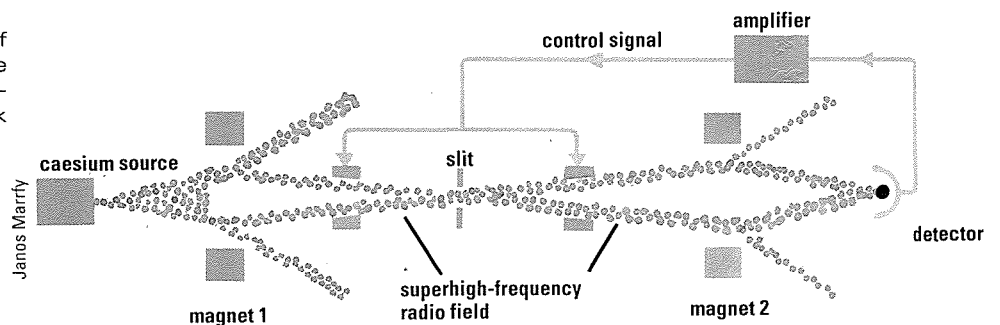
- **International Atomic Time** is time as defined by very precise atomic clocks at centres around the world, such as the National Physical Laboratory, Teddington, Middlesex, in southern England.

- **Coordinated Universal Time** is also known as Greenwich Mean Time. It is an internationally agreed atomic time that is occasionally adjusted by the addition or subtraction of one 'leap second' (at the end of the day on 30 June or 31 December) so as to keep in step with Earth Rotation Time, which is the time we live by. When this happens there are either five pips or seven pips in the time signal transmitted by the BBC (British Broadcasting Corporation) instead of the usual six pips.

The 'NPL second', is measured by the caesium atomic clock at the National Physical Laboratory near London.



Crown copyright/National Physical Laboratory



is so accurate that the second is now defined as the time occupied by 9,192,631,700 cycles of the particular microwave radiation produced by it.

An atomic clock can control the transmission of a radio signal that can be picked up by a clock on the mantelpiece of an ordinary house. The battery powered clock automatically tunes in to the signal and checks its time against the atomic clock at regular intervals.

Today there are various ways of measuring the World's time:

- **Earth Rotation Time** is based on the exact time the Earth takes to

An atomic clock uses a beam of atoms of the metal caesium. Each atom is like a tiny magnet pointing in a certain direction. Atoms pointing in the right direction are focused by magnet 1 so that they pass through a slit. Superhigh-frequency radio waves 'flip' the caesium atoms' directions, and magnet 2 focuses the flipped atoms on to a detector. The maximum number of atoms reach the detector when the radio frequency is exactly right. The vibrations of the radio waves are counted and displayed as the time.



Paul Raymond



CAUGHT IN ACTION

ROTATING PRISMS BENZENE SHUTTERS IMAGE CONVERTERS

NOTHING IS MORE GRACEFUL than a gymnast or a dancer leaping through the air. The movement is so fast that the human eye cannot follow it — only a camera can freeze the action and capture that moment in time for ever.

In a normal camera, light reflected from the subject is focused by the lens and prevented from reaching the film by the shutter. When you press the button, the shutter opens and allows light to reach the film. The period of time that the shutter is open

has to be matched to the speed of the movement being photographed.

For example, inexpensive cameras usually have a fixed shutter speed of 1/60th of a second and can only freeze the movement of someone moving at walking pace. More sophisticated cameras have shutter speeds down to 1/1000th or even 1/2000th of a second.

However, for many specialized purposes, such as sports coaching or the study of fast-moving wild life, 1/2000th of a second is nowhere near fast enough. In that fraction of a second, an insect's wings could complete a whole beat so any photograph of the insect taken at that speed would just be a blur.

To freeze the action of a bird flying or a tarantula striking, an exposure time between 1/16,000th

Gymnast Pascal Euizan does a back flip, illuminated by a series of strobe flashes. All light is excluded from the studio and the background is non-reflective matt black so that it does not show up in the final picture.

and 1/24,000th of a second is required. The fastest speed that can be achieved with a mechanical shutter is 1/4000th of a second, so some other way of making short exposures had to be found.

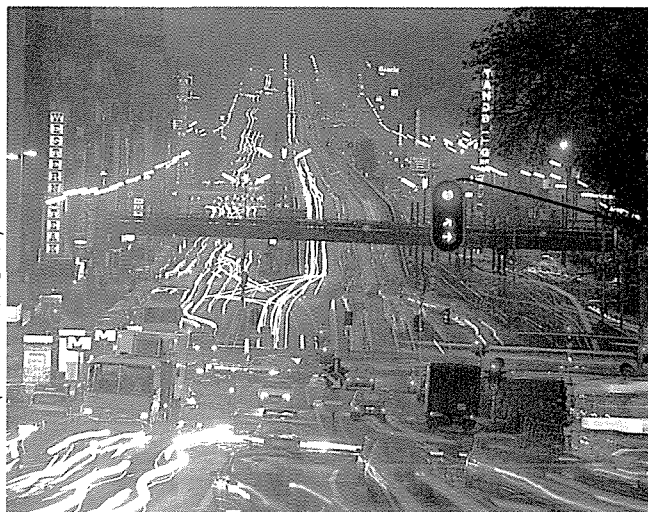
Short flashes

The simplest method found so far is to leave the shutter open and illuminate the subject with a very short flash of light. However, light can reach the film all the time that the shutter is open, so when using this method, pictures can be taken only in complete darkness.

Suitable flashes can be produced by a bank of electronic capacitors which shoot very high voltage electrical charges through a gas-filled tube. These discharge tubes can produce flashes as short as 1/24,000th of a second.

Since it is difficult to black-out a nest site or the branch of a tree, a lot of bird and insect photographs that look as if they were taken in the wild are actually taken in a studio. Alternatively they are sometimes taken at night, using black curtains draped around the tree branches to

Time exposures are made by leaving a camera shutter open for a period of time ranging from one second to perhaps 12 hours. Any movement in the picture shows as a blur. This type of picture is useful for capturing a period of time in a single photograph.



Spectrum Colour Library





Image-converter Cameras can take up to six hundred million pictures per second. This sequence of an air gun pellet breaking an ordinary matchstick was taken at only one hundred thousand pictures per second using an Imacon 792 camera (right). The pellet was travelling at 90 metres per second or 324 km per hour. The period of time covered by the sequence is eighty millionths of a second.



rotating prism. When the light hits the prism at a particular angle, it passes through and is focused on the film. As the prism turns it diverts the light away from the film, which can then move on one frame. The prism then continues to revolve until the next picture is taken.

The finished film is a sequence of frames rather like an ordinary movie film. The top speed of this type of camera is limited to 25,000 pictures per second because the rotation mechanism would break up into bits if it turned any faster.

Image-converter cameras are the fastest of all and can achieve speeds up to six hundred million frames per second. These are mainly used for studying the firing and impact of artillery shells and missiles.

Light is focused through a lens on to a photocathode device which converts the light into a beam of electrons. This is then focused on to a fibre-optic block which transmits the picture onto the film.

Electron beam

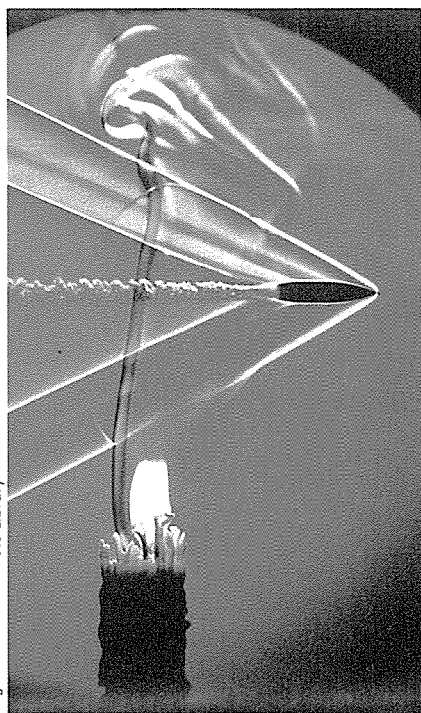
In a recent development of this technology, the electron beam is fed into a TV camera and the picture is viewed on a TV screen. If a permanent record is required, the TV picture can be photographed. This is extremely useful for research and development purposes.

shut out any moonlight and as much starlight as possible. Hidden trip switches are often used to trigger the flash – so when an animal lands on a branch or pops out from its hole, it triggers the trip switch and photographs itself.

When studying things such as electrical sparks, it is often necessary to take a series of photographs so that scientists can study each stage of a very fast event. The simplest type of camera for this job is a rotating prism camera. These can take up to 25,000 pictures per second, while a similar design that uses a mirror in place of the prism can take one million pictures per second.

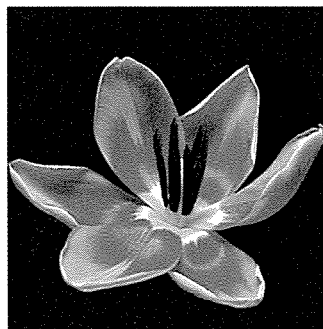
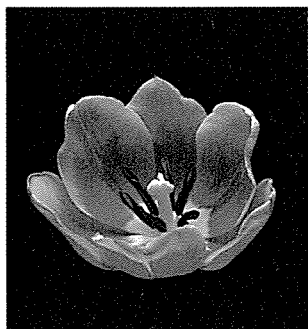
In rotating prism cameras, the light from the subject passes through a normal camera lens to a

Schlieren photographs detect invisible pressure changes in gases. Here the bullet is moving so fast that it creates a series of shock waves.



Edgerton/Science Photo Library

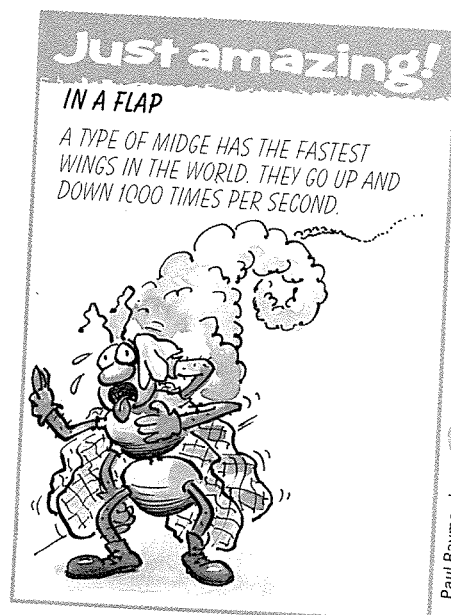
SPEEDING UP TIME



Sean Morris/Oxford Scientific Films

Time-lapse photography is a way of compressing long periods of time on to a short length of film. If a cine camera shoots one frame per second, an hour's action is condensed into 2½ minutes. This short time lapse is used to record events that happen fairly quickly such as a

crystal growing or chicks hatching out of an egg. A time lapse of one frame per hour is used to record slower processes, such as a flower blooming or a house being built. When screened, the whole process can be watched in a matter of minutes.



Paul Raymonde





Thames Water

SAFE DRINKING WATER IS vital for good health. Without it, most people would suffer from diarrhoea and sickness most of the time.

The microbes that cause disease do best when they have human waste matter – sewage – to live on. As eighty per cent of normal drinking water is pumped out of the rivers, it is vital to keep them free from human and animal pollution.

This is no problem at the start of a river. But towards the mouth, after all the waste water and chemicals from the factories and towns along the banks has been emptied into it, river water is usually heavily polluted. Nevertheless, there is nowhere else to get large supplies of water from, so to protect the people who drink it, many countries have legal controls on the:

- number of bacteria and other microbes
- number of pieces of solid human and animal waste
- quantity of dissolved salts in drinking water.

It is not easy to meet these standards because more and more human waste from inefficient sewage works and animal waste from factory farms gets into the rivers.

At a waterworks, the river water is first filtered through wire mesh screens to remove the rubbish. It is then pumped into reservoirs until required. These are stocked with fish, which makes them an angler's paradise. However, the real purpose of the fish is to act as a check that the water is clean.

When the water is drawn out of the reservoir, it is filtered through a

Water supply networks are being fitted with remote control systems so that one man can control many water treatment works.

Tunnels up to 2.5 m across are being built to keep large towns supplied with water. This one will be longer than the Channel Tunnel.



Thames Water

WATERWORKS

series of beds containing sand. The sand in the first bed is quite coarse, so the largest particles of dirt are trapped there. The next bed contains finer sands and so on. During this process, some microbes are killed by exposure to the air and others get eaten by other microbes.

Nevertheless, there are nearly always some harmful bacteria left, which are dealt with by dissolving a measured amount of chlorine gas in the water as it leaves the waterworks. If you find the water from the tap at home tastes odd, that is probably the chlorine.

In hilly areas, the purified water is then pumped uphill into an underground holding reservoir. In flatter districts, the water is pumped into

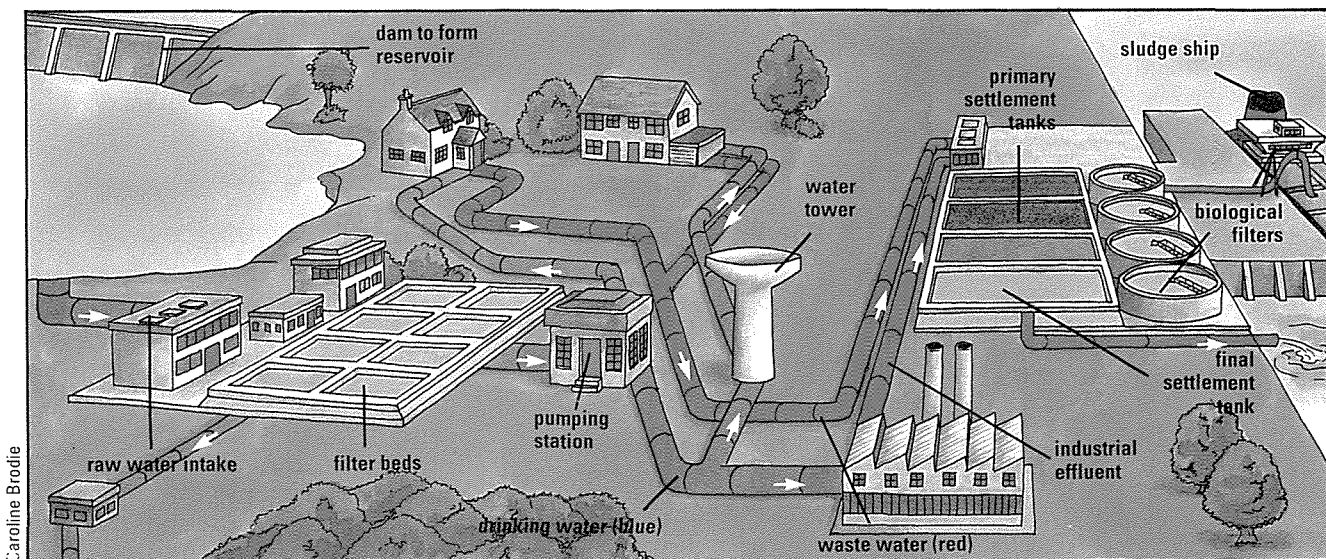
water towers around 30 metres high. When somebody opens a tap, the water rushes downhill, through the pipes and gushes out of the tap.

Electric pumps

Large towns use too much water to store in this way, and so large electric pumps force the purified water through a network of pipes to the consumers. Up to a quarter of the water leaving a waterworks escapes from leaks in this network.

Inside the house, small copper pipes carry water to the kitchen, the bathroom and the lavatory. When you pull the plug out, the water flows away through the waste pipe. The contents of the lavatory disappear into the soil pipe.

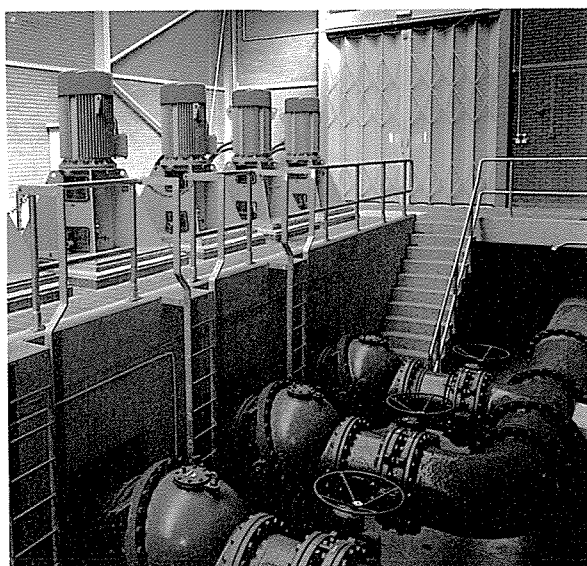




Caroline Brodie

Underground pipes form a network joining up the various parts of the water and sewage system. The pipes are laid so that the water can run downhill from the reservoirs in the hills right through to the point where purified sewage re-enters the river.

Electric pumps, each one using as much power as a dozen small cars, feed purified water into the water mains serving a large town. The 'steering wheels' are for opening and shutting the enormous valves that turn the water on and off.



Yorkshire Water Authority

In modern houses, the waste pipes and the soil pipe connect with the soil stack, which runs up the outside of the house. This disappears into the ground, joins up with the house drains under the pavement and eventually meets the sewer which runs along the road.

The sewers serving each road

join up into larger trunk sewers and eventually reach the main sewers which run into the sewage works. All the pipes are laid with a gentle slope down to the sewage works so that the flow of water carries the solid waste with it without pumping. Drains in the road also feed rainwater into the sewers.

Minced solids

At a sewage works, the first job is to remove the biggest bits of rag, tree branches and grit. Sometimes the sewage is then passed into a mincing machine which minces all the remaining solids until they are fine enough to go into the primary settlement tanks.

Here the solid sludge falls to the bottom of the tank and is removed for treatment elsewhere. The liquid sewage is then sprinkled on to a biological filter. These are beds of stone about two metres deep. So many bacteria live on the stones

Oxygen-breathing bacteria eat and so purify the liquid sewage. Large paddles mix air into the liquid in the tanks to make sure the bacteria can breathe properly.

that the surface gets covered with a jelly made of billions of bacteria. As the liquid trickles through the filter, these bacteria eat most of the remaining waste matter.

Dead microbes

The water draining out of the biological filter is much cleaner than the liquid that flows in, but it still has to go through the final settlement tanks. Here, lots of dead microbes and algae sink to the bottom as sludge.

At some sewage works, the biological filter has been replaced by the Activated Sludge Process, in which a high concentration of bacteria is mixed with the incoming sewage. This mixture is then stirred up and air is mixed in with a set of electric paddles so that the bacteria breed rapidly and eat all the particles of organic matter in the water. Again this creates a sludge which requires more processing.

All the sludge in the sewage works is collected for treatment in one place. Sometimes bacteria are encouraged to eat the sludge, but it can also be used as a fertilizer. However, since various poisonous heavy metals like cadmium have been found in sewage sludge, it has tended to be dumped at sea or burnt. Both methods of disposal anger environmentalists, but as yet no ideal solution has been found to this age-old problem.

HUMAN WATERWORKS

Just like a waterworks with its beds of sand for filtering water, the human kidney is equipped with a million filter tubes called glomeruli. About 200 litres of plasma – the watery part of the blood – enters the kidneys every day through a large artery and the glomeruli filter out the waste. Most of the water, plus many useful substances like glucose, are returned to the blood stream while concentrated liquid waste – urine – is excreted.

ZEFA



MAKING TRACKS

18/12/120100



A 24-track mixing desk is as difficult to operate as a jet aircraft - it can record, adjust and combine up to 200 separate sounds

IN THE STUDIO

THE RECORDING STUDIO IS the heart of today's music industry. And, with the ability to take a raw performance, correct mistakes, polish and improve it, it has, in many cases, also become the soul.

The studio is the link between the musician and the vast majority of his or her audience. Its most basic function is to record a performance on magnetic tape - the tape then being used to manufacture records, cassettes or compact discs.

The control room

There are two main parts of a recording studio - the 'studio', or room, where the musicians perform and the control room where the technicians operate the recording equipment. Both are soundproofed. This means that no unwanted noises can interfere with the

MAGNETIC TAPE

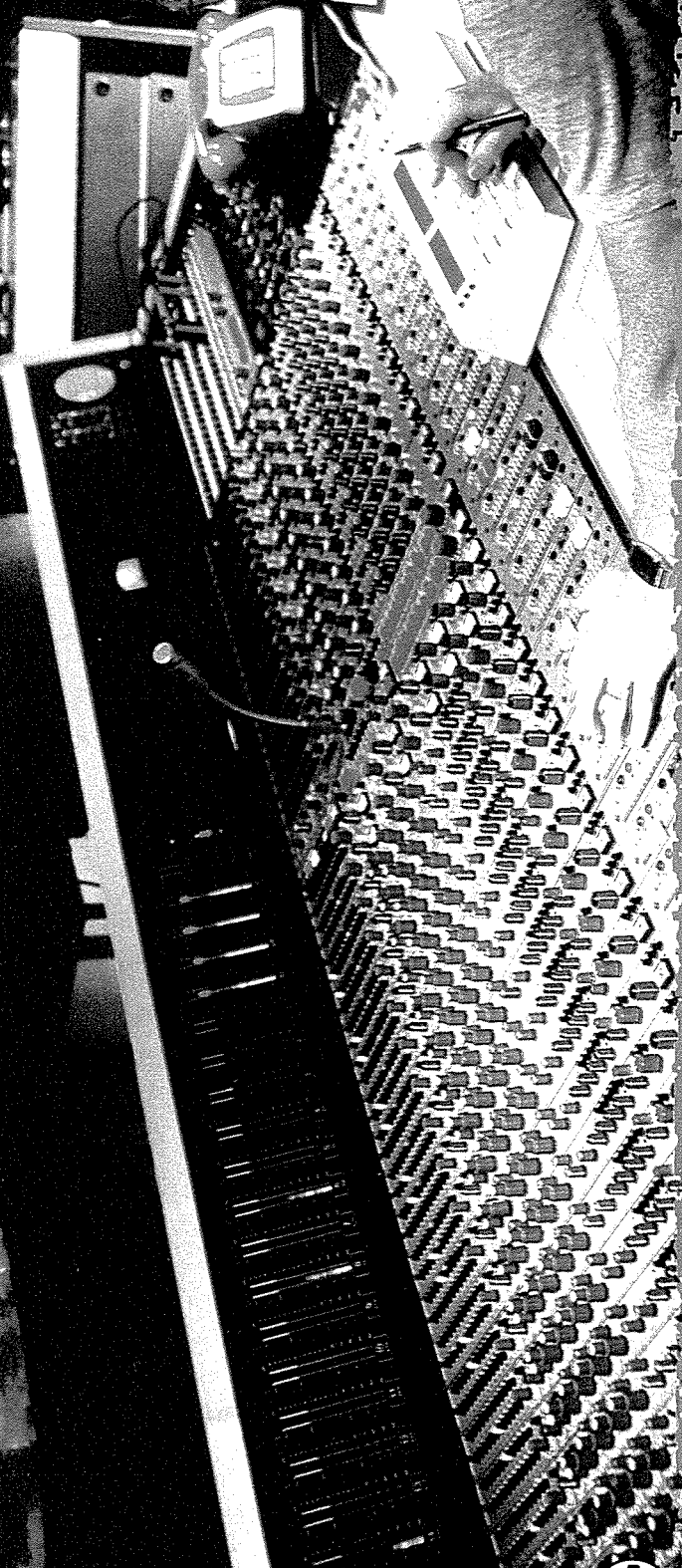
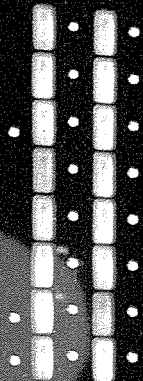
recording and the technicians hear only what they want.

Some recording studios have electronic room simulators which can make an acoustically neutral room sound like a large or small concert hall - or even a bathroom. Some musicians, however, prefer to record in an acoustically 'live' environment. Stewart Copeland, drummer of the rock group The

THE MIXING DESK

Police, for example, was known to record the drum tracks of Police records in rooms that he felt sounded 'right' for the particular song.

A song is normally recorded in stages - each musician performing his or her piece individually. The musicians may either 'read' their parts or play along to a 'guide track' - a rough recording of the complete



Tony Stone Photo Library London





Gavin Cochrane

A band starts a recording session by recording a 'guide' rhythm and vocal track. The engineer feeds this via headphones to the musician or section he next wishes to record. The players 'lay down' their parts by playing to the guide, which is erased when the song is finished.

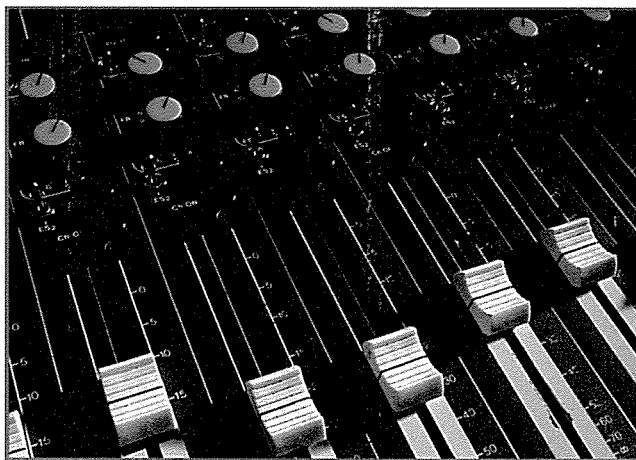
song — heard through headphones.

The usual order is drums, then bass guitar, guitar and keyboards, then lead vocals and backing vocals. Other instruments such as 'brass' (trumpets, trombones and saxophones) or 'strings' (violins, violas and cellos) or perhaps additional guitars or percussion may be added.

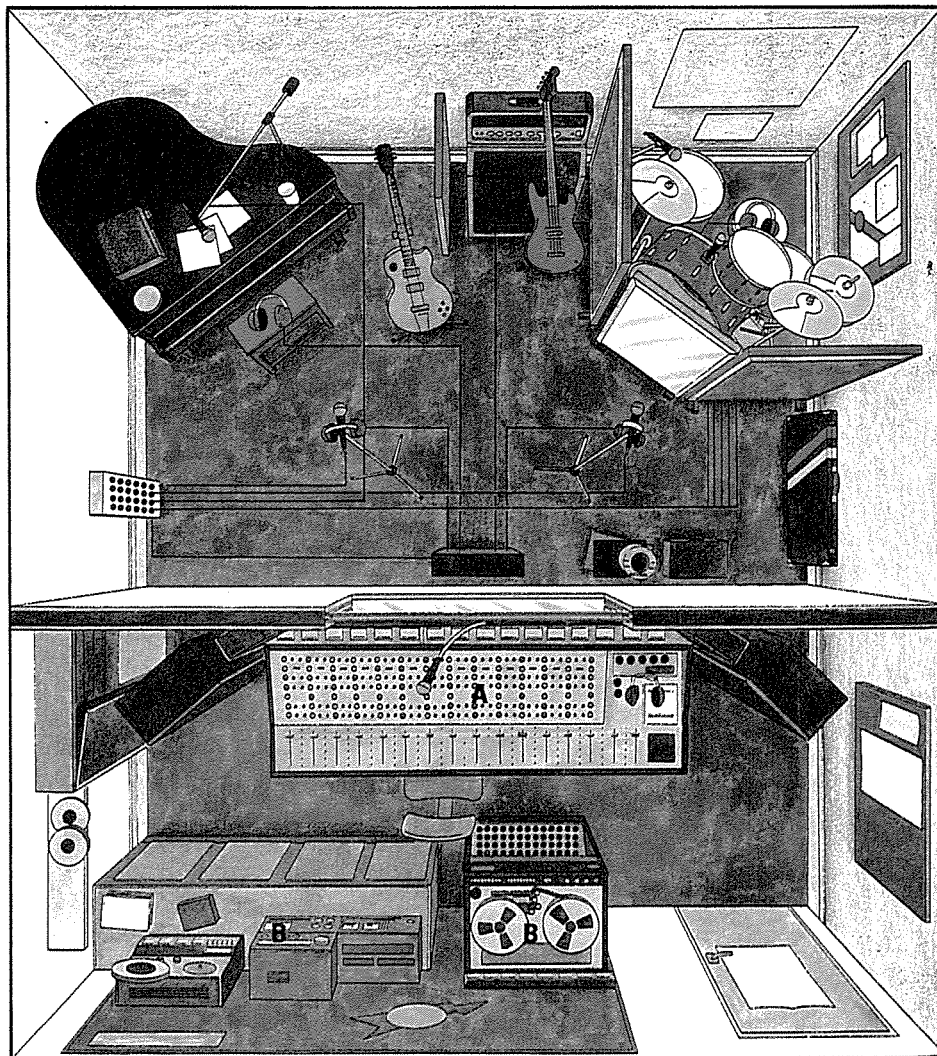
The vocals and acoustic instruments are usually recorded through a microphone. Microphones are transducers — they change sound signals into electrical signals. There are several different types. The one normally used for vocals, for

The fader controls are basically tone controls, allowing the engineer a fine degree of adjustment.

The recording studio is divided into the studio (top) where the musicians perform, and the control room (bottom) with the mixing desk (A) and recording equipment (B).



Ace



Caroline Brodie

sound recorded by microphone.

The individual sounds are recorded on magnetic tape. Professional recording tape is of a much higher quality than that found in most audio cassettes. It is also much wider — usually 25mm across compared with the 3.8mm of cassette tape, and 792 metres long compared with 121 metres for a C90 cassette. Whereas cassettes have two tracks (that is, two distinct recording/playback areas) — one on each side — professional tape has room for 24 tracks.

Time code track

Although there is room for two more tracks, the outside edges of the tape are not used for sound because of the danger of damage due to mishandling. On one edge, however, there is the SMPTE track. Named after the American Society of Motion Picture and Television Engineers who introduced it, 'simply' is a universal time coding which simply records time, second by second.

Overdubbing

This means that the individual sound tracks can be synchronized, allowing extra tracks to be recorded later; also existing tracks can be corrected or improved. These techniques are known as overdubbing. SMPTE also allows two 24-track machines to be linked for a 48-track recording.

The various parts of the recording process may be carried out



MAKING TRACKS

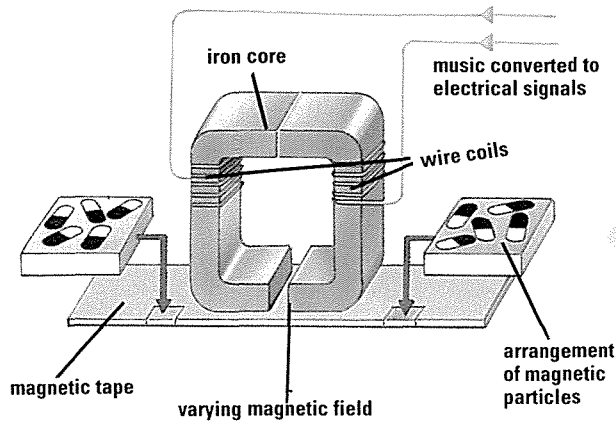
directly, using analogue (non-digital) electronics. The recording process may also be done using digital, computer techniques. Digital music recording requires a huge memory, just five seconds of music takes up an enormous megabyte of memory – the equivalent of a large, 500-page novel.

John Houghton

Between the musicians and the tape recorder lies the most important part of the recording studio: the mixing desk. Each sound source – vocalist, guitar, drum, mike and so on – has a channel on the desk. The channel is the route through which the sound waves, translated into electrical impulses, travel on their way from sound source, through the mixing desk to tape.

Production

Important though it is for the recording process, the mixing desk only really realises



The record head on a tape recorder is an iron core, wrapped with coils of wire. Sound is converted into magnetic patterns. The variations in the magnetic field in the gap at the bottom of the core cause the magnetic particles coating the tape to vary their arrangement. These patterns are recorded permanently. The play head does the opposite job, reading the taped magnetic imprint and converting it back into sound.

Cutting a disc involves mixing the multitrack tape (left) down on to a 2-track stereo master (right), then cutting a record blank.



Mitsubishi Pro Audio Ltd

STUDIO JARGON

Bounce down – to combine tracks on the same recorder

Drop-in – re-record a portion to correct a mistake or improve that portion

Dubbing – copying one track or tape to another

Effects – devices such as echo, phasing, harmonizers that enhance the original recording

Graphic equalizer – a tone control system that displays the full range of audio frequencies and allows sections, such as the bass or treble, to be altered

Mix-down – to re-record multi-tracks on to a 6.35mm stereo master.

Overdubbing – adding tracks to an existing work

Reverb and echo – to repeat the original signal at slightly lower successive levels or different frequencies

its potential once the recording is complete. The production takes place once all the sounds have been committed to tape. The mixing desk is the master control, allowing the technician to vary the volume and quality of each channel.

All musical sound is made up of many frequencies and the mixing desk allows any frequency to be boosted or cut back. A vocal that is too thin, for example, can be given an extra bassy quality by boosting its bass frequencies. A bass drum can be brought forward, a guitar brought up for a solo and so on.

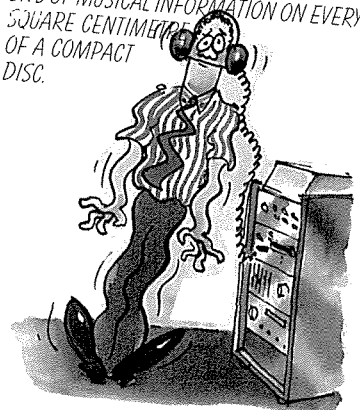
Echoes

The producer can also add effects such as reverberation or digital delay. Reverberation, or reverb as it is called, is the addition of echo to enrich a sound. Digital delay can be used in several ways.

Just amazing!

BLIP, BLIP, BLIP...

THERE ARE OVER 26 MILLION 'BLIPS' OR BITS OF MUSICAL INFORMATION ON EVERY SQUARE CENTIMETER OF A COMPACT DISC.



Paul Raymonde





A digital mixer with 16 channels. Sampling the audio signal at up to 50,000 times a second, a digital recorder converts the sound into on/off pulses.

possibly on either side.

The most popular mixing desks are known as Solid State Logic (SSL) desks. These have built-in computers that can memorise every setting on the desk. So the producer can happily try many different combinations of sounds and technological effects.

If the sound is held up for a few thousandths of a second then re-played over itself many times, an effect called phasing is created in which the sound seems to sweep on and on. Or the sound can be held up longer to create the true echo effects required on a dub record. Digital delay can also produce an effect known as chorusing in which the frequency of a vocal is slightly altered and played back many times. This makes a single voice sound like a choir.

Once the sound has been equalised and effects added, the finished tracks must be mixed down on to a two-track master tape: one for the left and one for the right channel. The aim is for a full stereo image.

The stereo image

So drums, for example, may be spread across the image by putting the bass in the centre, the kick drums at either side and the cymbals left centre. Rhythm guitars may be balanced symmetrically around the centre with the lead vocals in the centre and harmony vocals

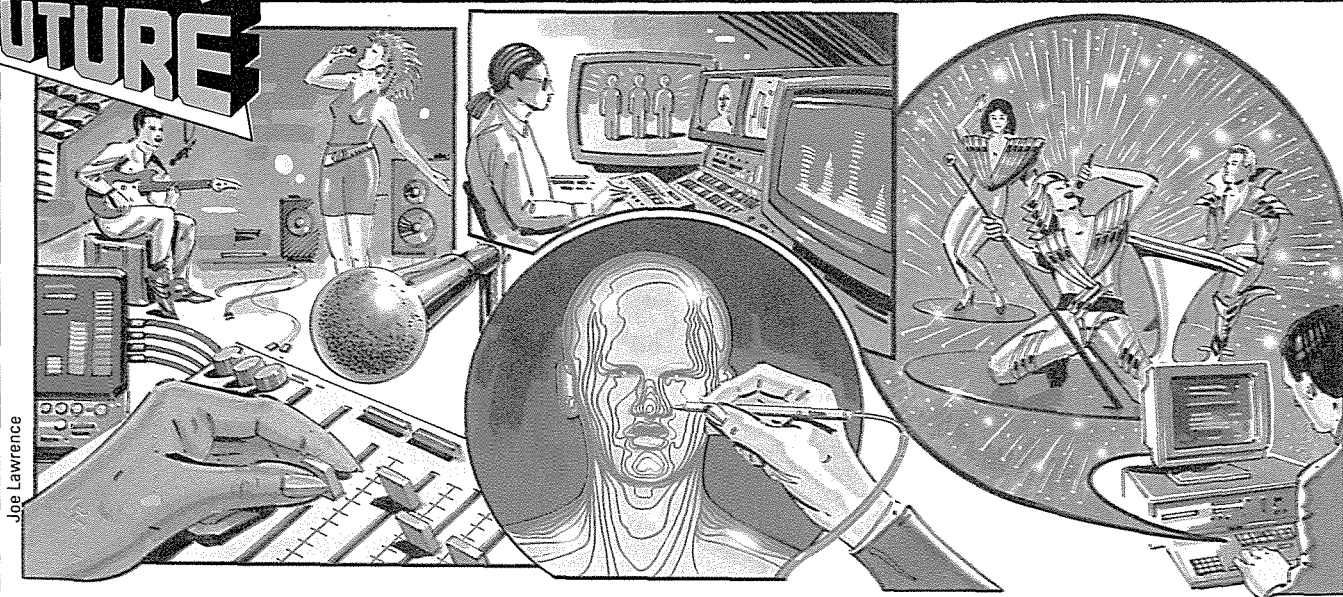
Mobile recording takes the control room and all its equipment to a concert hall.



Mobiles usually have at least two multitrack machines so that the tape does not run out before the end.

INTO THE FUTURE

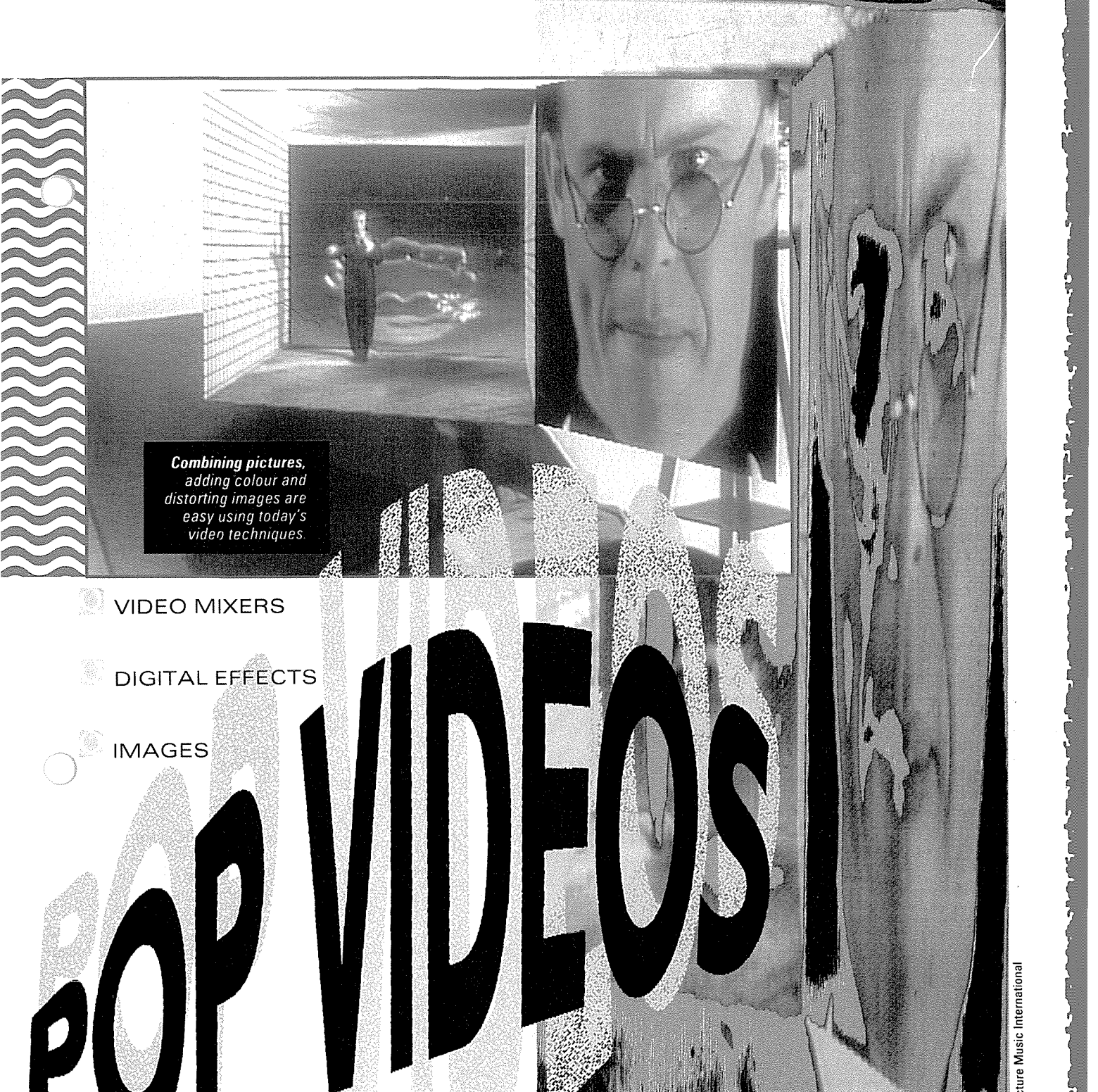
THE GHOST IN THE MACHINE



▲ Sampling techniques – the ability to create music from a single fragment of sound – will allow record producers to take a sample of guitar, piano, bass and vocal and create a completely new song.

▲ Computer-generated graphics will then be used to create the rock band of tomorrow, perfectly honed to match the new sound, able to work continuously for as long as required and perfectly behaved.

▲ The band will be promoted with its own pop videos and a whole, high-flying career launched through a ghostly creation that exists only in the mind of the creator and the memory of a computer.



Combining pictures, adding colour and distorting images are easy using today's video techniques.

VIDEO MIXERS

DIGITAL EFFECTS

IMAGES

POP VIDEOS

VIRTUALLY EVER HIT SONG HAS a video to go with it. But this is not just a short film of the group singing their latest record — computer-generated special effects, colour separation and sophisticated digital techniques are all part of the paintbox used to promote the product.

Producing the sound for a pop video is the easy part. It is usually taken from the studio recording of the song. This gives the director of the video an exact length of time to work to. It may also give him or her ideas for the content of the video, which

he or she will discuss with the group. The song may also provide critical moments when the shot or scene has to be changed in time to the music. These will be worked into the shooting script or the storyboard.

A *shooting script* is a list of all the shots to be used, incorporating details of the action, camera angles and movements. A *story board* is a cartoon-strip version of the shooting script, giving an artist's impression of the main shots of each sequence.

Shooting

The original footage for a pop video can be shot on film or video. It does not have to be shot in the order dictated by the shooting script. The

footage can be shot in any order and put together later.

The performers mime to a recording of the track, and the images are then processed and edited to fit the music so that sound and vision blend together perfectly. Next, any special effects are added. If any of the original footage is shot on film, it will be transferred to video so that special effects can be incorporated.

One of the most important techniques used in video making is chromakey, or colour separation overlay (CS). Chromakey is a technique for combining one image with another in one frame — it can be used to show a group against an unexpected background, for example. When you see a video with a

Picture Music International



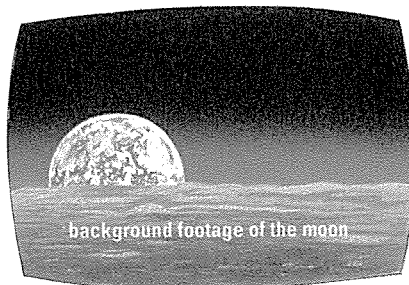
SPECIAL EFFECTS

A very important technique in pop video making is DVE – Digital Video Effects. It is a tool for manipulating video images. When you see an image suddenly shrink down and whizz around the screen, DVE has been used. Video signals are digitized and stored as digital information in a computer. They are then manipulated – by the system's own programs or by keypad and joystick. Each signal manipulation takes about 1/25th of a second. The result is an image that moves so fast that we see it as one flowing, seamless piece of hi-tech action.

group flying through the air, or driving a car through a cartoon landscape, this is made possible by chromakey.

Pure colour

The first step in using chromakey to get these kind of effects is to record the two sequences which are to be combined. The images for the background sequence can be real, hand drawn cartoons or computer generated images. To make the foreground sequence, the group are videoed against a plain, pure colour



background footage of the moon



artist against pure colour background



combined image - artist on the moon

Simon Critchley



Sinclair Stammers/SPL

Putting together a video requires a bank of video machines – to play original footage, and record the result.

– usually pure blue or pure green. The members of the band being filmed must not have any of the pure colour in their clothes.

A machine called a vision mixer is used to bring the band and background together. The two sequences are run simultaneously. The vision mixer analyses the one with the group in. Wherever it finds the pure colour, it replaces it with the background image. Elsewhere it leaves the foreground image. So the final sequence shows that band performing against the required

background scenery.

Image manipulation by computer is another of the pop video maker's most important tools. Video images can be stored in a computer as digital data, then manipulated in the most extraordinary ways.

Stretch and spin

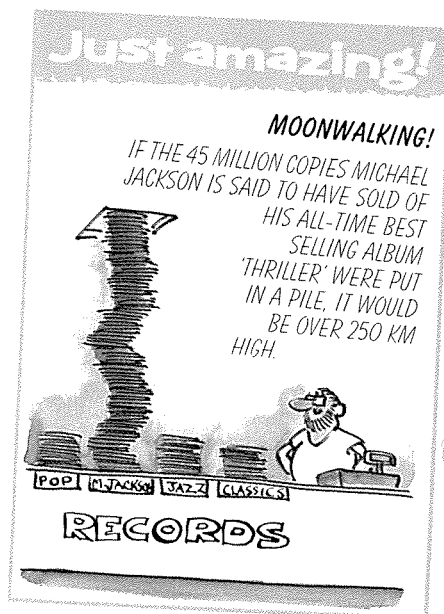
Images can be stretched, compressed, turned upside down, mirrored left to right, spun or put into false colours. On modern machines, images can be painted in – or painted out – at the editing stage, without having to reshoot the original footage.

Manipulating video images in this way is extremely expensive – editing suites hire out at £200 an

Performing on the Moon is simple: the artist is shot in front of a pure colour background, then the vision mixer fills in the colour with the background Moon shot.

hour or more. Hundreds of thousands of pounds are spent on producing pop promo videos before they are distributed to the TV companies.

If the video is exciting enough to be shown on TV, it is worth millions of pounds in record sales to the record company and the group themselves.



Paul Raymonde



■ BATTERY CHICKENS

■ GROWTH PROMOTERS

■ QUALITY CONTROLS

FACTORY FARMING

Computer carving the carcass of beef, which is held by mechanical arms. The computer decides exactly where to make the cuts.

THE FOOD INDUSTRY TODAY starts on the farm. No longer do pigs grub about in the meadow or chickens peck in the farmyard. Rolling fields have, in many instances, given way to huge buildings.

In today's fast-moving world, the customer is looking for consistent quality in food, and a low price. The result is the supermarket, designed to sell vast quantities of food as quickly as possible. The message to

the farmer is clear: the only way to satisfy the demand for vast amounts of cheap food is by intensive farming.

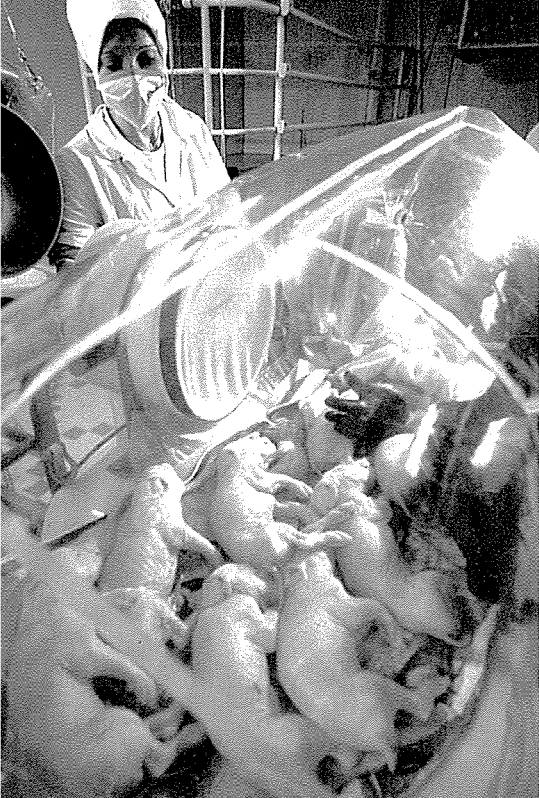
Cooped up

The modern farm has much in common with an industrial factory. Nearly all the eggs in Britain, for example, come from just 400 farms, where there are flocks of more than 20,000 birds in one building. The biggest chicken farm in the world,

however, is in Ohio, USA, where five million hens lay nearly four million eggs every day. In these mass 'coops' the chickens get adequate food and water, are protected from foxes and other predators and are kept in hygienic conditions.

What is not known is whether these 'battery' chickens have enough room to move about, or whether they suffer stress or other problems. What is certain, of



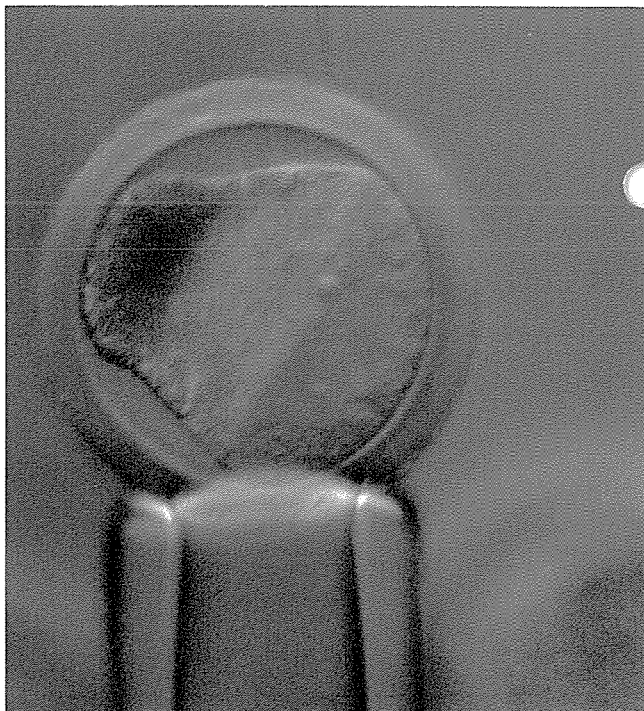


Newborn piglets are laboratory reared and kept completely clean in a germ-free environment.

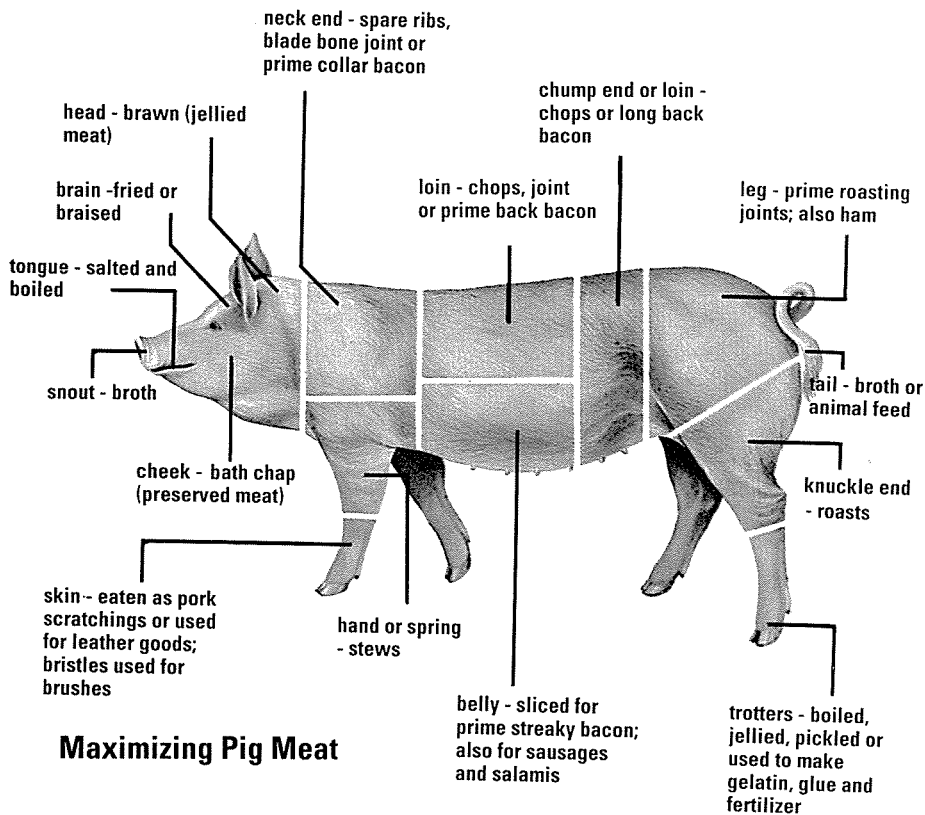
Genetic engineers isolate a single gene that can promote growth. In this highly magnified shot, extra copies of a gene are introduced in a newly fertilized egg.

Pigs are now bred so that their meat is less fatty. Butchers divide the pig into various cuts, ensuring minimum waste. The heart and spleen are made into pâté, and the pancreas eaten (as sweetbreads) or used to make insulin. Blood and leftovers may be used for sausages.

Daudier/Jerrican



University of Adelaide



Maximizing Pig Meat

in three weeks rather than the natural seven. They will then be monitored and fed by computer to bring them to the optimum slaughter weight – between 50 and 120 kg each – as rapidly as possible.

Pig in the middle

The factory pig cannot follow its natural inclination with regard to food. In one of the newest systems, each pig in a pen of 70 or 80 pigs wears a computerized ear tag. Food is provided at a special feeding stall that only one animal can enter at a time. The ear tag is detected by a sensor and depending on whether the pig has had its daily allowance or not, the pneumatically operated trough opens or stays closed. The factory pig simply cannot 'make a pig of itself' – which is just as well, as, if it had unlimited access to concentrated food, it would prob-

Just amazing!

HAPPY CHICKS

CHICKENS AND TURKEYS GAIN UP TO FOUR PER CENT MORE WEIGHT IF THEY HAVE 'WALLPAPER' MUSIC TO LISTEN TO AND BABIES' TOYS TO PLAY WITH.



Paul Raymond

Elaine Keenan

course, is that if they were reared naturally the cost of their eggs would soar.

One reason for the mass rearing of chickens is that their meat is more popular today than ever. The average man or woman now eats ten times as much chicken as he or she did 50 years ago. Over the years, farmers have managed to rear ever-increasing numbers of chickens. As a result, the relative price of a chicken has fallen over the

last 15 years by about 60 per cent.

A similar story applies to the pig. There are about 7 million farm pigs in Britain and some 60 million in the USA. Rapid advances in factory farming have ensured that most pigs lead a totally unnatural life.

Computer fed

A factory pig may start life as a result of artificial fertilization and have its birth accelerated. It is normal for piglets to be force-weaned



Battery hens live out their lives in cramped conditions without ever seeing a farmyard. In recent years there has been a move away from battery farming towards free-range or barn farming. Newly hatched ducks (inset below) are herded into crates and sorted manually according to their sex.

wide. The plastic is perforated with anything from 100 to 500 tiny holes per square metre, so both sunlight and rainwater can pass through.

Underneath the plastic it is warm and humid, like a mini-greenhouse — just right for plant growth. The plastic does not even have to be removed and disposed of because it is photodegradable — designed to break down naturally in sunlight.

Early harvest

Covering means that crops can be sown earlier than usual, because although it may be a cool spring day above, under the plastic it is as warm as midsummer.

Many crops are now grown under plastic, including potatoes, carrots, sweetcorn and beet. Carrots can be harvested three weeks earlier if they are grown this way. This is extremely important for the farmer because, if he can get his produce to market before his rivals, he can get a better price.

Furthermore, some crops are more productive when grown under plastic. In one trial, there were 45,000 corn cobs over 30 cm long per hectare under plastic compared with just 17,200 in a normal field. Also, as with the carrots, they were ready for picking up to 10 days earlier, which again meant better market prices.

Off to market

After the farmer has done his job, the produce must be packed up and shipped off to market and then on to the shops. Technology has helped here, too.

Take apples, for example. Researchers at the University of Michigan, USA, have designed a tiny computer, shaped like the fruit, called an 'impact detector device'. It records



Weiss/Jerrican

with added vitamins to compensate for the lack of sunlight and green-stuffs. Antibiotics are also added to prevent disease. Copper is used as a growth promoter — this has led to the poisoning of sheep after pig slurry was used as manure on grazing land. Hormone growth promoters are also used, despite fears that they may be passed on to humans.

Forced growth

Growth hormones are made by genetically engineered microbes that have had the gene from the animal inserted into them. They are either injected into the animal or given as an implant under the skin. Animals treated with growth hormones grow faster and can be taken to the market earlier, thus guaranteeing a better price.

The idea of accelerating growth (known as 'bringing on') is not unique to the farming of livestock. Crops, too, can be — and increasingly are — forced. One of the most common ways of doing this is to grow crops under transparent plastic strips about one to two metres

Perforated plastic strips allow sun and rain to pass through, providing a sheltered environment for crops and encouraging higher yields.



Farmers Weekly

ably eat itself to death!

Such systems are thought to create stress in the animals. There is also concern about the level of artificial additives to pig feed, but much research needs to be done in this area.

Pig feed is normally brimming

WHAT'S YOUR POISON?

For most victims of food poisoning, the worst consequences are vomiting, diarrhoea and a few days in bed. But for some, particularly the sick or elderly, food poisoning can be fatal. Poor handling, hygiene and storage, plus inadequate cooking or re-heating encourage unwanted bacteria. The most common are:

- **Salmonella** — bacteria thrive on warm meat and poultry; also found in eggs and egg products
- **Campylobacter** — often found in raw and poorly cooked food and unpasteurized milk. It is responsible for twice as many food-poisoning cases as salmonella
- **Staphylococcus aureus** — bacteria thrive on ham and bacon that other bugs find too salty
- **Listeria** — most likely to be found on 'chilled' pre-cooked convenience foods. The germ survives low temperatures and some boiling.



ORGANIC FARMING

All farming is – in a sense – organic because in chemistry this term means 'carbon-containing', and all molecules in living things are based on carbon. However, the modern meaning of organic is closer to 'natural'. It means farming without using artificial chemicals such as fertilizers, pesticides and herbicides. Farmers work 'within nature' using animal manures, garden compost and leaf moulds as fertilizers, and employing old-fashioned methods such as crop rotation, which prevents the soil becoming exhausted.

the intensity and frequency of any knocks and squeezes the skin receives. Using this computerized apple, it is possible to find out the best way for packing apples and which parts of their journey are the bumpiest. One interesting discovery is that most are damaged as they are put into bags after picking.



Nasty taste

Another important task for the computer is detecting bad coffee beans. Rogue coffee beans, called 'stinkers', have a terrible flavour and, when ground up, can ruin a whole pack of coffee. Although a stinker looks perfectly normal, when it is

Coffee beans entering a computerized sorter pass an infrared light source. Any bean that glows is bad, so it is detected and blown out.

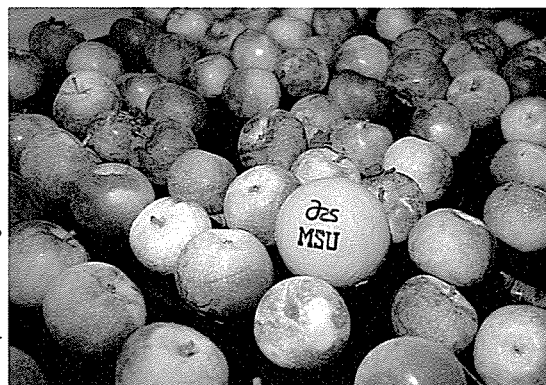


The incubation room in a plant cloning laboratory, Australia; here identical copies of one banana plant are produced.

Phillip Hayson/Colorific

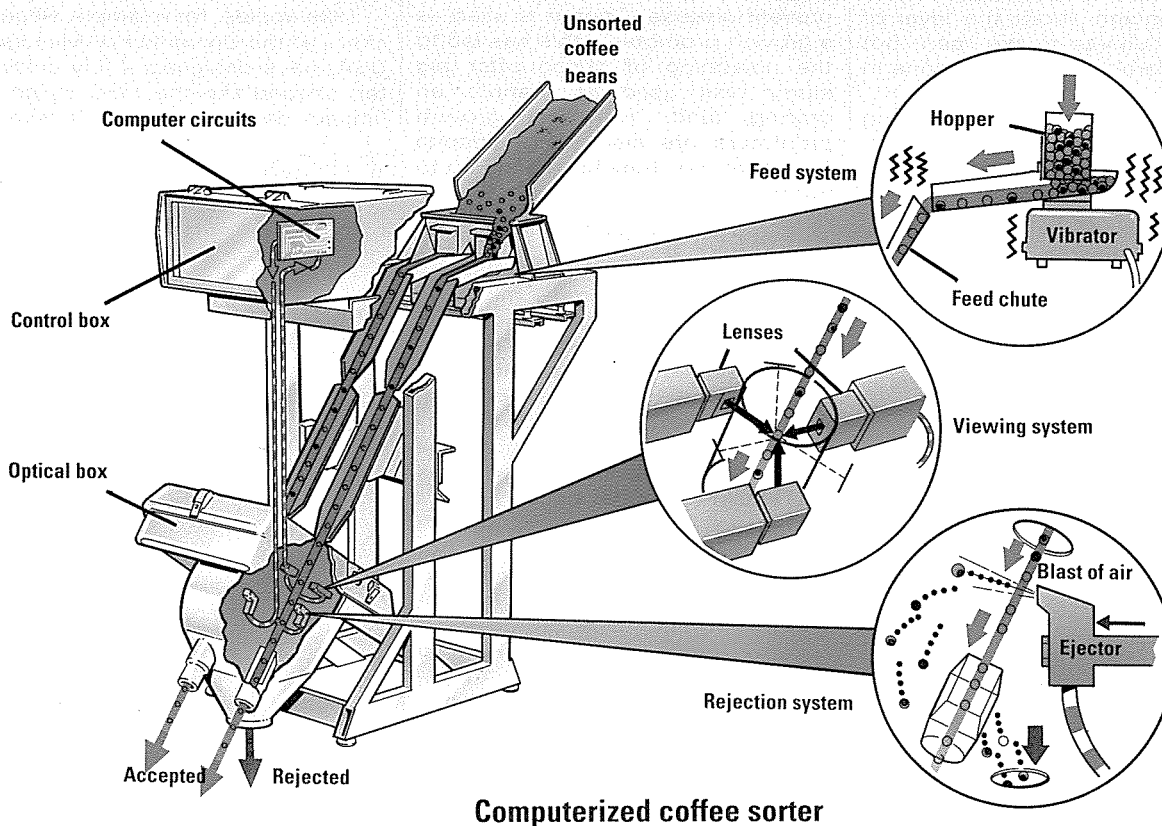
viewed under ultraviolet light, it glows.

Colour sensors, called photocells, measure the type of light reflected from the coffee beans as they fall down a chute. These sorting machines work at incredible speeds, scanning the chute 1,200 times every second. Any bean that does not match the standard colour is blown into a reject box by a blast of air. Using this system, a single bean is inspected up to 20 times as it passes the 'magic eyes', ensuring it is fit to be ground into coffee.



US Department of Agriculture

An impact detector shaped like an apple detects any bumps and bruises that the fruit receives while in transit.



Computerized coffee sorter



PLANT CROPS GROWING IN fields outdoors may seem romantic and peaceful. Corn waves in the wind and ripe apples glow on the orchard trees. But is outdoors the best place for farm plants to grow?

The waving corn could be attacked by rust fungus, which would ruin its growth — and the farmer's livelihood — while the wind that makes the corn wave is drying it out. Meanwhile, grubs could be boring into the ripe apples, tainting their flesh and spoiling them.

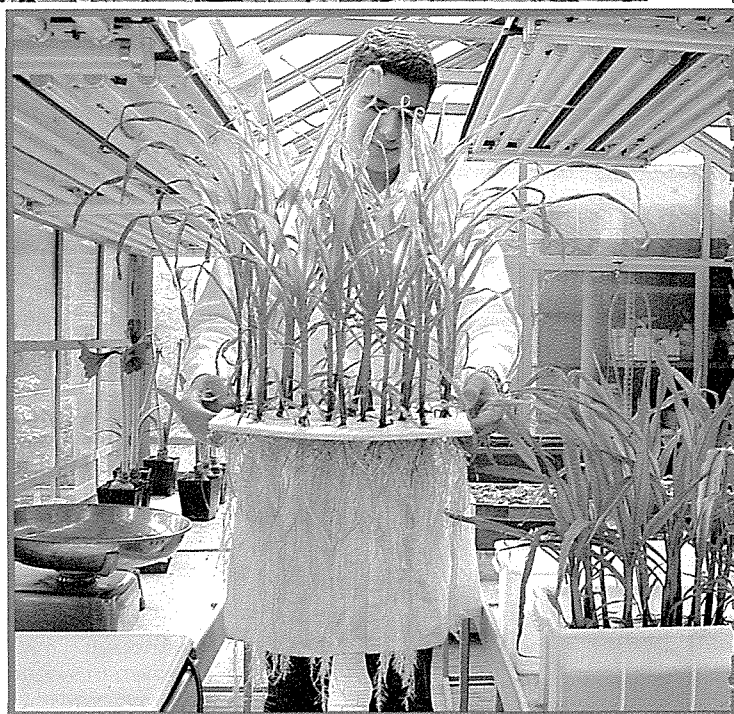
Greenhouses

If, instead, plants were grown indoors, they could be kept in almost ideal conditions, fed exactly the right amounts of water and nutrients. Pests and diseases could be kept out. With the right types of plants, farmers could harvest more of the plant material so less is wasted. The question is: is it worth it?

Building a huge greenhouse is expensive, and regulating the conditions such as temperature and humidity uses a great deal of energy. In addition, excluding all pests and diseases would be costly. Ba-

Protected from pests and weather in near perfect conditions, indoor yields can be 50 times those outside.

Without soil, these plants flourish with their roots dipped directly into water containing all the nutrients they need.



lanced against the expense is greater productivity and easier harvesting conditions. Also, crops could be grown in places where plants could otherwise never grow.

One way to make indoor fields more productive is to do away with soil altogether! This form of cultivation began when the soil-less Wake Island in the Pacific was made fertile by growing vegetables directly in water. Large tanks were filled with water and nutrients. Up to 40 kilograms of sweetcorn, tomatoes, lettuces, beans and marrows were harvested from each tank each

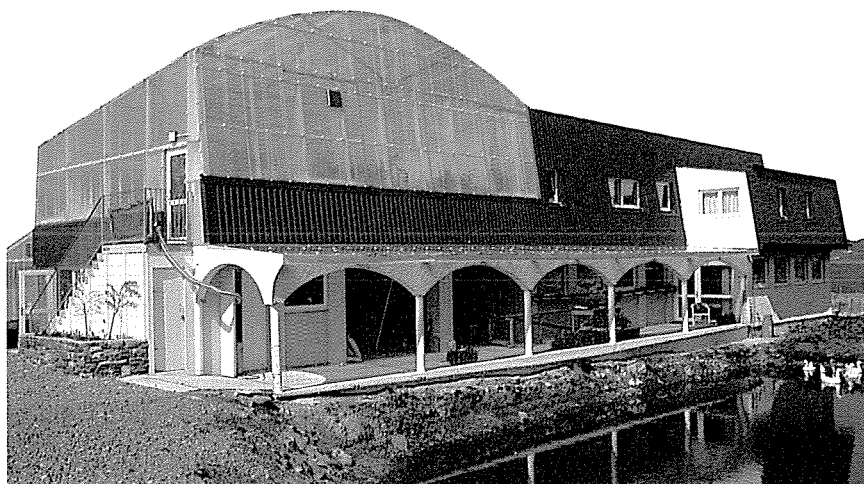
week throughout the year!

Depending on the exact method used, growing plants without soil is known as *nutriculture*, *aggregate culture*, *chemiculture*, *nutrient film culture* — or by the more general term of *hydroponics*.

Nutrients

In soil-less culture, the plant grows in water that carries a carefully selected 'cocktail' of dissolved nutrients. To run at greatest efficiency, the farmer must also know exactly which nutrients his crop needs at each stage in its growth cycle, and





even from day to day depending on the general temperature and weather.

Computers can be programmed to open ventilators or pump the water round faster, depending on the conditions. The nutrient levels are monitored automatically and topped up when necessary.

Feeding solution

In the water culture system, shallow trays or racks hold a slow-moving stream of the 'feeding solution'. A wire frame a few centimetres above holds a supporting medium such as rockwool, plastic granules or rice husks. Young plants are placed in the supporting medium and their roots dangle into the water below, sucking up nutrients.

In other systems the plants are rooted in a growing medium such as clean sand or gravel, plastic granules or cinders. The feeding solution is either sprinkled onto the medium and trickles through, or is pumped up from below.

Viard/Jerrican

Banana trees growing in Scotland! Under triple-glazed windows of the Hydroponicum (above) – the purpose-built hydroponics unit at Achiltibuie, West Ross – there is enough heat and light to grow such fruit as bananas, grapefruit and strawberries.



Simon Fraser/SPL

list of advantages when crops are raised without soil:

- You do not have to worry about building up the fertility of the soil, or exhausting it after several seasons.
- The technique is especially suitable in barren, rocky or sandy areas. Diseases hiding in the soil are also not a problem.
- Most seedlings grow into mature plants – outside the proportion that develop is far smaller.
- Indoor plants are clean, ready for the shops. Crops are almost entirely weed-free. They are easier to harvest and give bigger yields. More uniform in size, they are also easier to sort, pack and transport.

Water saving

Although hydroponic crops are grown in water, the system actually saves water. The water vapour given off the plants' leaves and stems (in a process called transpiration) is collected as condensation on the glass or plastic roofs and walls of the greenhouse and recycled back into the plants' water supply. Because it is collected by condensation, transpired water is remarkably pure – it has, in effect, been distilled.

Plants can also do without sunlight. In a pilot study, vegetables were grown hydroponically under controlled artificial light during winter in New York. The idea was to make them competitive with the vegetables brought year round,

across country, by truck from Mexico or California.

The yield per area was up to ten times bigger than the same crops grown in an ordinary greenhouse – and up to 50 times greater than out in the open field. The water was recycled too, and the system used only one-tenth the water that would be needed to irrigate crops grown outdoors.

In the future, grasses and similar plants could be grown on animal effluent – that is, liquid sewage. The water vapour they give off, when condensed, is pure enough to drink. So hydroponic installations could double up as water-purifying plants in arid areas.

Some scientists have suggested combining indoor plant-farming with fish-farming. The fishes' wastes enrich the water, providing additional nutrients for the plants to feed on.

Just amazing!

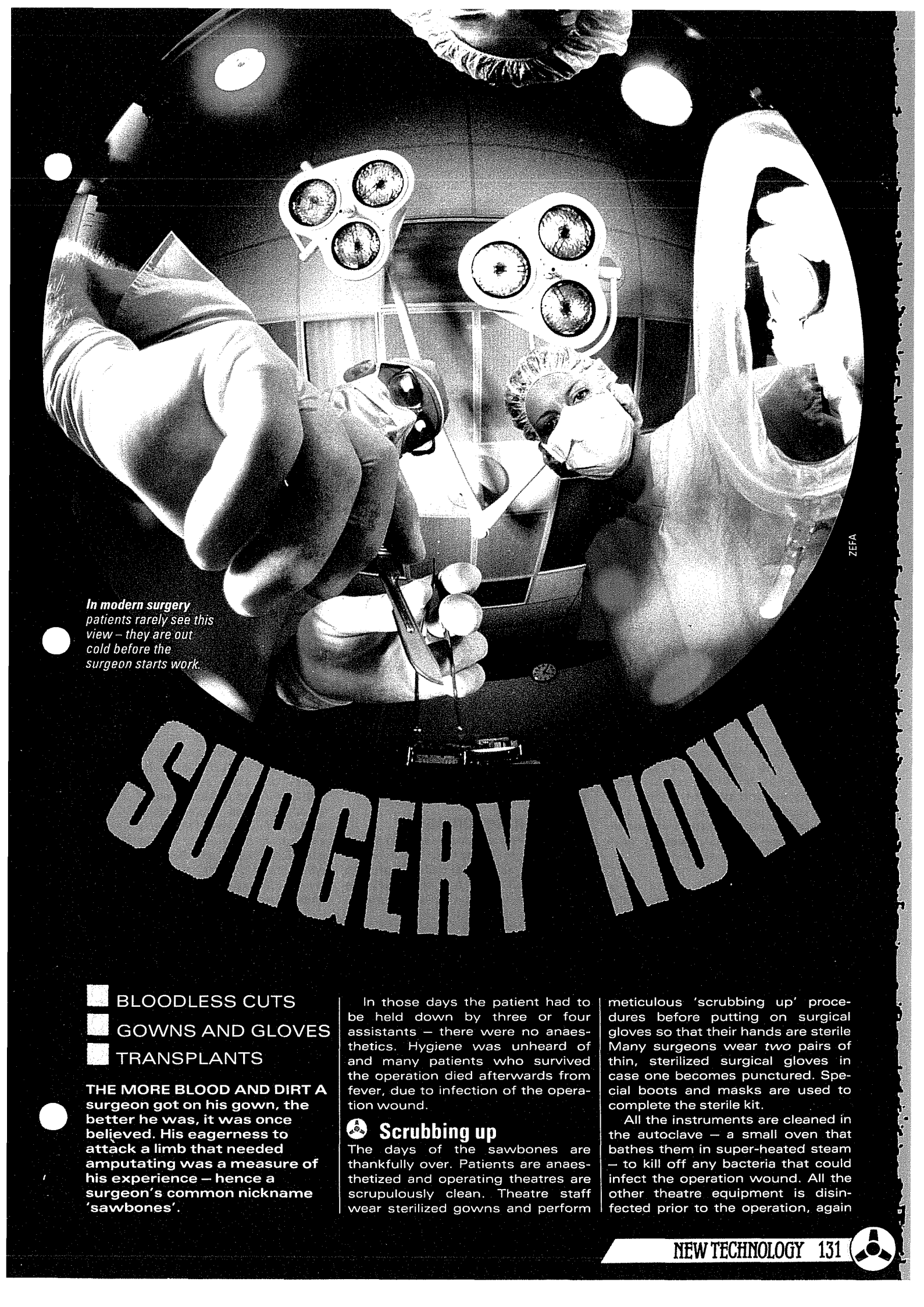
THE BIG ARTIFICIAL APPLE
SOME NEW YORKERS EAT VEGETABLES THAT HAVE NEVER SEEN SUN, SOIL OR NATURAL RAIN. THE FOOD IS GROWN INDOORS, IN WATER AND UNDER ARTIFICIAL LIGHTS.



Paul Raymond

This robot arm is computer controlled to move the pots of flowers around so that they get equal lighting from all sides and grow straight.

Many crops – including tomatoes, marrows, beetroots, beans, sweetcorn, lettuces, celery, peas, peppers and courgettes – are now grown using these soil-less systems. Researchers point to a long



In modern surgery patients rarely see this view – they are out cold before the surgeon starts work.

SURGERY NOW

■ BLOODLESS CUTS

■ GOWNS AND GLOVES

■ TRANSPLANTS

THE MORE BLOOD AND DIRT A surgeon got on his gown, the better he was, it was once believed. His eagerness to attack a limb that needed amputating was a measure of his experience – hence a surgeon's common nickname 'sawbones'.

In those days the patient had to be held down by three or four assistants – there were no anaesthetics. Hygiene was unheard of and many patients who survived the operation died afterwards from fever, due to infection of the operation wound.

Scrubbing up

The days of the sawbones are thankfully over. Patients are anaesthetized and operating theatres are scrupulously clean. Theatre staff wear sterilized gowns and perform

meticulous 'scrubbing up' procedures before putting on surgical gloves so that their hands are sterile. Many surgeons wear two pairs of thin, sterilized surgical gloves in case one becomes punctured. Special boots and masks are used to complete the sterile kit.

All the instruments are cleaned in the autoclave – a small oven that bathes them in super-heated steam – to kill off any bacteria that could infect the operation wound. All the other theatre equipment is disinfected prior to the operation, again



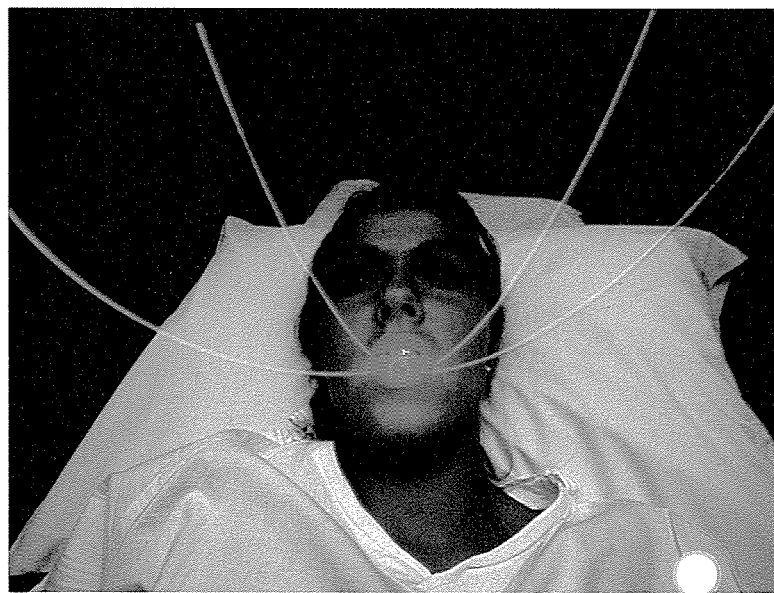
Sterilized surgical instruments are laid out in a standard order before an operation begins. This set is designed for plastic surgery.

Laser light from a low-powered argon laser is directed by four fibre-optic waveguides to treat a cancerous tumour in a woman's throat.

tures. If a laser is used instead of a scalpel, the operation can be carried out more accurately, burning away only the tumour and leaving the healthy tissue undamaged. An added advantage is that the laser produces a bloodless cut. Its heating, burning effect welds the wounds, as it cuts away the diseased tissue.

Without cuts

These days surgeons avoid cutting open a patient, where possible. Instead they use an instrument called an endoscope. This consists of a flexible



Alexander Tsiaras/SPL

James Stevenson/SPL

to ensure any germs are destroyed.

The operating theatre itself has special air filters to keep the air circulating and clean, removing any airborne bacteria. The patient is also disinfected before he or she is brought into this sterile environment. Before the initial cut is made, the area around the cut is given an extra clean just to be on the safe side. This total dedication to cleanliness is one of the greatest advances ever made in surgery.

New tools

Until recently, though, many of the other tools of the old 'sawbones' were used. The scalpels used to open up the patient, the retractors that held the cut open and bone saws were much the same as they had been for centuries. But now many new surgical techniques have been developed, taking advantage of new technology.

Welding retina

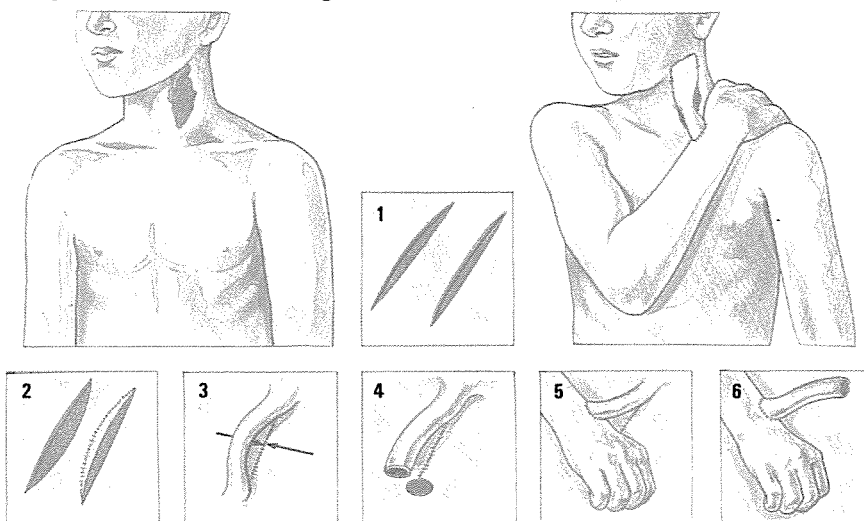
These days surgeons often use lasers. Torn bits of the retina (the light-sensitive part of the eye) can be 'tacked' back on again by firing a laser beam at the torn edges. This has the effect of 'welding' them back on to the rear of the eyeball. Even a detached retina can be re-attached by accurate firing of a precisely focussed laser beam.

A serious eye disease called glaucoma (an increase in the pressure within the eyeball) can be treated using specialized lasers. These lasers actually punch holes in tissue rather than just melting it. By shining laser light through the cornea, a surgeon can relieve the pressure without opening the eye with a knife.

Burning tumours

Laser beams are also used in treating tumours (a tumour is an overgrowth of abnormal cells). Tumours can be cut out, but this may be dangerous to surrounding struc-

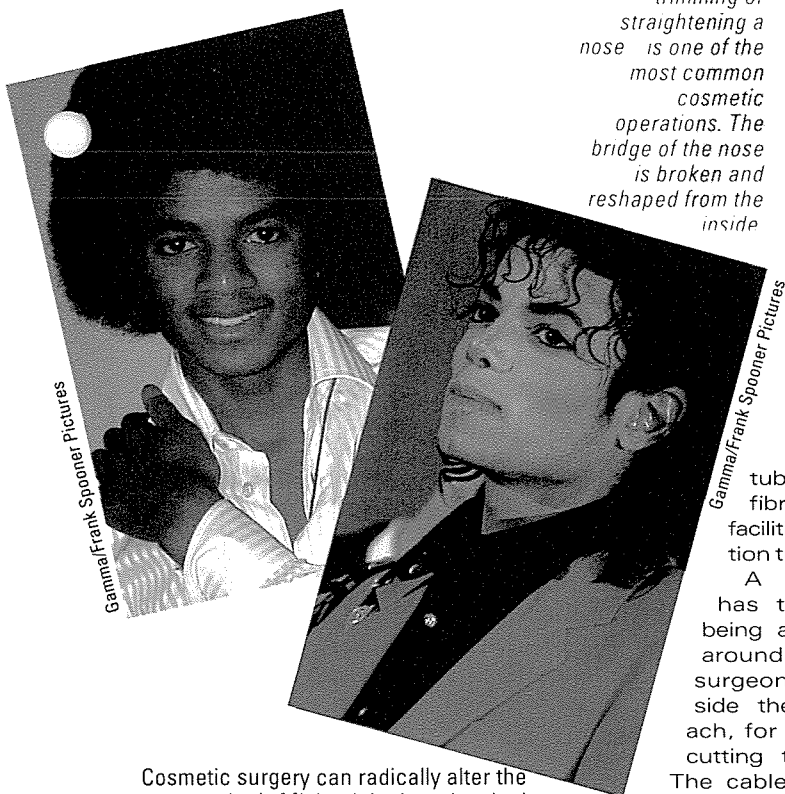
Free-flap surgery is used to repair damage to visible areas like the face by taking tissue from other, less visible parts of the body. Here, a flap of flesh is lifted from the patient's stomach (1 + 2) and the two sides of the wound are sewn together (3). The flap of flesh is then detached at one end and formed into a tube (4). The cut end of the flap is sewn on to the wrist to ensure good blood supply (5). Next the other end is detached from the stomach (6) and the tube is sewn on to the wound.



John Houghton



IMAGE CHANGING



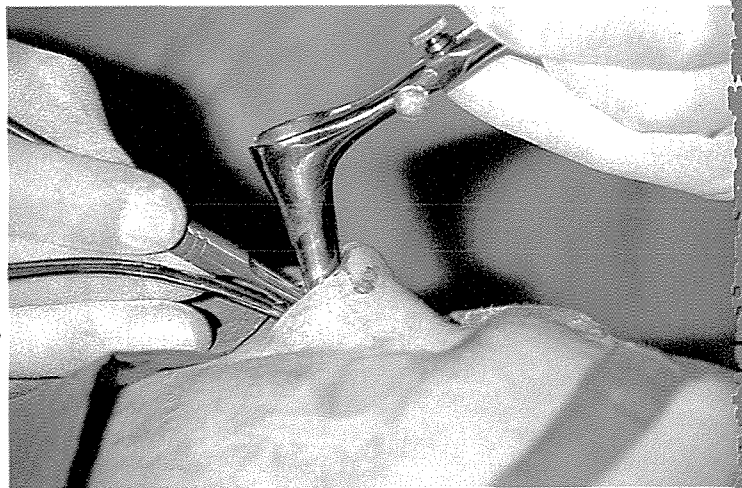
Gamma/Frank Spooner Pictures

Gamma/Frank Spooner Pictures

Cosmetic surgery can radically alter the way you look. Michael Jackson has had his lips narrowed, the shape of his chin altered, silicon implants put in his cheeks and his nose trimmed down several times. He has also had his skin bleached, the shape of his eyes altered, eyeliner permanently tattooed around his eyes and his hair permed.

Cosmetic surgeons also commonly remove unsightly birthmarks, enlarge women's breasts by implanting bags of silicone and remove wrinkles by tightening the skin in a so-called face-lift. Silicone implants are also used to give extra fullness to lips and earlobes. Thighs can be reduced in size by sucking out the extra fat, using a technique called liposuction.

The 'nose job' trimming or straightening a nose is one of the most common cosmetic operations. The bridge of the nose is broken and reshaped from the inside



tube carrying opticle fibre cables and other facilities, including a suction tube and forceps.

A fibre-optic cable has the advantage of being able to carry light around corners, so the surgeon can see right inside the patient's stomach, for example, without cutting the patient open. The cable can be inserted into the mouth and down the throat. If the operator sees something that could be abnormal, the forceps can cut away a sample for analysis.

The endoscope can be connected to a video and television monitor so that a team of specialists can view the abnormal area. If surgery is needed, laser light can be channelled into the area and the operation performed without ever having to cut open the patient.

Microsurgery

Surgery has now progressed to the point of being able to replace limbs that have been cut off in an accident. Sewing back an arm or a leg is relatively easy, but making the limb work again needs microsurgical skills. These incredibly delicate techniques are needed to reconnect nerves and tiny vessels so that life, feeling and control of the limb can be restored.

If a severed limb is to stay alive it must be kept cool so that it remains in 'suspended animation'. All the arteries, veins and nerves on the remaining stump must be identified so they can be re-attached to the correct ones on the severed limb. The bone must be wired together and every tiny nerve and vessel sewn up. Lastly, the muscles and tendons have to be sewn together and the skin closed.

Human kidneys have to be kept alive while they are being transplanted. This unit pumps blood through the kidney to keep it functioning.

If all the vessels are reconnected correctly, the limb will flush pink. After 6–8 weeks, the nerves usually heal and work again, and feeling returns to the re-attached limb.

Brain breakdown

Microsurgery is also being used to treat certain brain disorders. In treating a debilitating condition called Parkinson's disease, a totally new – and controversial – technique has been developed.

In Parkinson's disease, a certain brain chemical appears to run out. The chemical in question is called dopamine. (Without it, uncontrolled muscle twitching occurs.) The tiny area of the brain which produces it, inexplicably, stops working.

Embryo drug

The conventional treatment for Parkinson's disease involves the patient taking artificial dopamine (L-dopa) for the rest of their life. But recent research has developed a way of replacing lost dopamine.

If tissue from a human embryo is transplanted into the area of the brain that is low in dopamine, the patient's symptoms may be relieved. The symptoms don't return

Just amazing!

CHOPS AND CHANGES

IRISHMAN WILLIAM MCILROY HAD MORE THAN 400 OPERATIONS IN 100 DIFFERENT HOSPITALS DURING HIS LIFETIME, COSTING THE BRITISH NATIONAL HEALTH SERVICE MORE THAN £2.5 MILLION.



Paul Raymond



Hank Morgan/Rainbow





The Telegraph Colour Library

exactly the same as the tissue from the donor.

The recipient's immune system does not recognize the foreign tissue and treats it as if it were an invader. So his or her body attacks the new organ and rejection occurs. One way of overcoming this problem is to give the patient antirejection drugs such as cyclosporin that prevent the immune system from doing its job. The problem is that the body is then open to attack from other diseases as its defences are low.

Matching tissues

Another way is to 'tissue type' the donor and recipient very carefully before the operation, to make sure that both are compatible. This is done by taking blood samples and checking them for similar genetic

Eye operations are incredibly delicate and have to be performed using a microscope. Here, the lens is being removed – because it has become cloudy – and being replaced by a new plastic one which will restore the patient's sight.

because the embryo's dopamine-producing cells take over production of the chemical. Transplanting the embryo cells in just the right place involves new microsurgical techniques.

Another area of enormous surgical advancement is organ transplants. But there are several complications involved in organ transplantation. The most important is tissue rejection. This occurs when the tissue of the recipient is not

material. The best chance of finding an exact tissue type is with a close relative who has the same genetic background. Once the tissue type has been matched, the operation can proceed.

Heart transplant

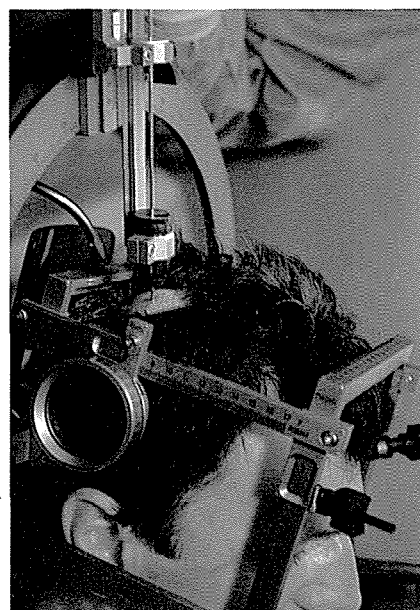
If a heart is being transplanted, the patient will have to be connected to a heart-lung machine. This takes over the function of both the heart and the lungs so that the heart can be removed and replaced without cutting off the circulation and killing the patient.

Kidneys can be transplanted, so freeing the patient from a kidney machine. The liver, too, has been successfully transplanted, sometimes with the bowel. This is particularly important as no artificial liver machine has yet been developed.

Spare flesh

Following a severe accident, the victim may need plastic surgery. A face may need to be rebuilt. But where is the spare flesh to reconstruct the damaged area to come from? The easiest way to avoid the problems of rejection is to take it

To treat brain tumours, you first need a sample. A local anaesthetic is given, then a 3 mm puncture is made and a tiny sample extracted with a needle.



Gamma/Frank Spooner Pictures

from the patient's own body.

The spare tissue is usually taken from another healthy area of the person's body in a technique known as free-flap surgery.

Saving face

To rebuild a face after accident or surgery, a flap of flesh may be partially cut away from the chest, arm or stomach. Once the 'free-flap' of flesh is growing well and the wound where it was severed from the body is healing nicely, the free-flap is moved to the area of the face where it is needed. When the full thickness of skin is grafted on in this way, scarring, and shrinking of the graft, is minimized.

AS GOOD AS NEW



Gamma/Frank Spooner Pictures

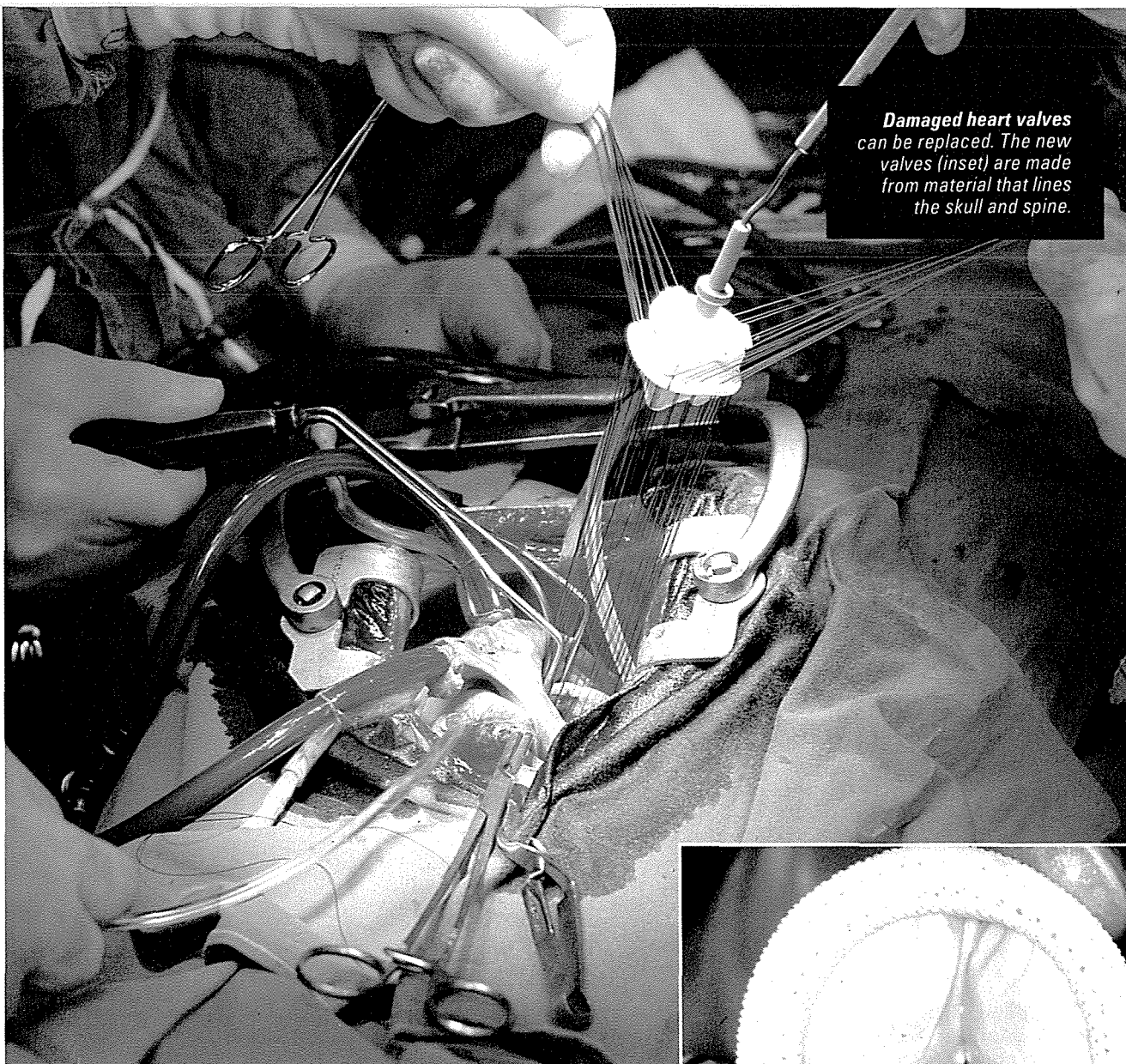


Gamma/Frank Spooner Pictures

Extraordinary operations are now possible. If you have lost an arm or a leg, it can be sewn back using microsurgery techniques. Ten-year-old Timmie Mathias (top) had his head sewn back after a road accident. The strong ligaments connecting his spine and his skull were snapped when he was hit by a lorry and dragged along in its wheels. After a six-hour operation he is now almost as good as new.

Ten-year-old Meng Xin (above right) was run over by a train which destroyed her left forearm and thigh. Her hand was usable, however, and in an 18-hour operation, her left shin-bone was used to reconstruct her arm to give her use of both hands.





Damaged heart valves can be replaced. The new valves (inset) are made from material that lines the skull and spine.

Martin Dohm/SPL



MEDICAL MIRACLES

-  RESTORING SIGHT
-  HEART PACEMAKERS
-  NEW JOINTS

NOT SO LONG AGO, IF YOU went blind, became deaf or lost a limb, nothing could be done. But now, medical science has developed new techniques to treat almost every condition – even those once thought incurable.

It is even now possible to replace the lens of a human eye. Cataracts and diabetes can cloud lenses and patients used to be told that nothing could be done for them. But now new materials and techniques

can restore sight. The operation involves opening up the clear part in the middle of the eye – the cornea – using a microscope. The old lens is removed and an artificial one implanted.

Total deafness was once untreatable and the patient just had to live with it. But now, with modern electronics it is possible to implant a microelectrode directly into the inner ear. The electrode is activated by a hearing aid. This hearing implant is still in the early stages of

development and is limited to use in certain types of deafness. For example, people with hearing nerve damage cannot use this method. But the potential of this new technique is enormous.

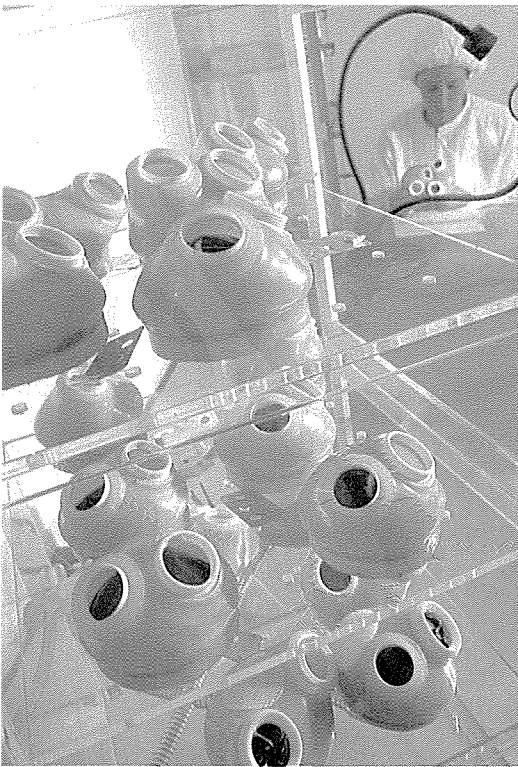
David Leah/SPL

Pacemakers

Small electric shocks can be used to stimulate a diseased heart. Normally the heart has its own pacemaker which produces an electrical impulse along special conducting fibres. When this wave of electrical excitement spreads across the heart tissue, it contracts, pumping the blood around the body.

Some diseases interfere with the conducting tissue and the heart will not contract correctly. The treatment is to implant an artificial pacemaker, to take over the job of the





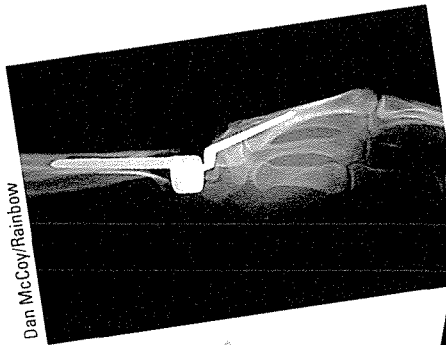
Complete artificial hearts have been implanted. But it is impossible to make a pump as durable as the original.

natural one, restoring normal heart function. A small electrical unit is installed inside the patient's chest cavity with electrodes connected to the heart itself.

Heart attack

Electrical stimulation is also used in emergency cases when the heart stops. When a heart attack occurs, the heart must be restarted within three to four minutes — otherwise brain damage is likely to occur due to lack of oxygen.

A machine called a cardiac defibrillator is used to restart the heart.



An artificial wrist joint in position, seen on an X-ray. The new joint allows the patient to have full movement of the wrist

A man-made hip joint is made largely from stainless steel for strength, it has a plastic socket to allow smooth movement.

Stainless steel and plastic are used for a new knee. This combination 'self-lubricates' the joint.

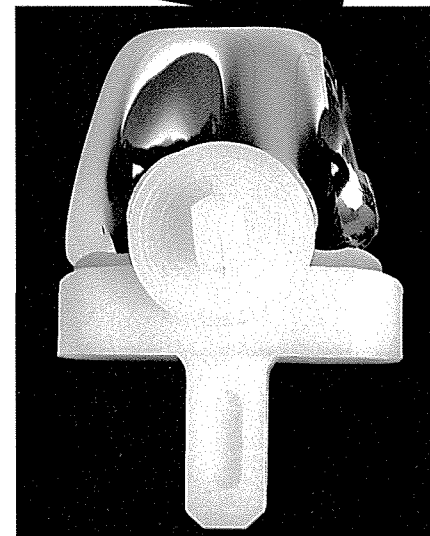
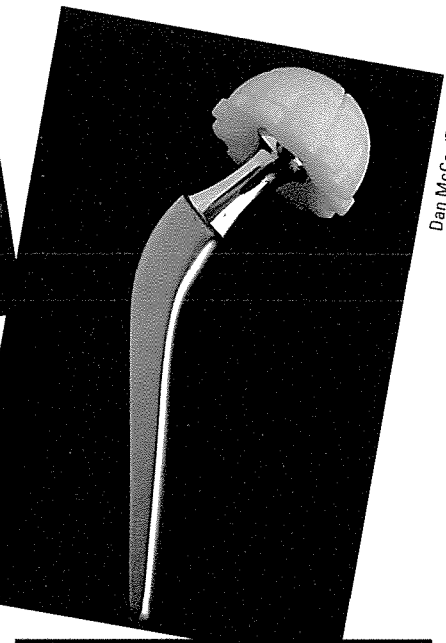
When a heart attack occurs, the heart muscles go into a state of flutter — or fibrillation. The jolt of electricity from the defibrillator will stop this flutter and restart the heart.

Diabetics suffer from a malfunction of the pancreas and many have to inject themselves with a substance called insulin at least once a day to control their blood sugar level. But devices are now available that deliver the vital insulin around the clock in a continuous slow stream via a small pump.

These new insulin-infusion devices are worn in a pouch on the belt. They are connected to a vein via a special needle that is attached to a tube which plugs into the machine.

New joints

When the joints in our bodies wear out, they can now be replaced with artificial ones. The surgeon cuts out the damaged joint and drills out the shaft of the bone. He fills this shaft with a special type of 'cement'. The

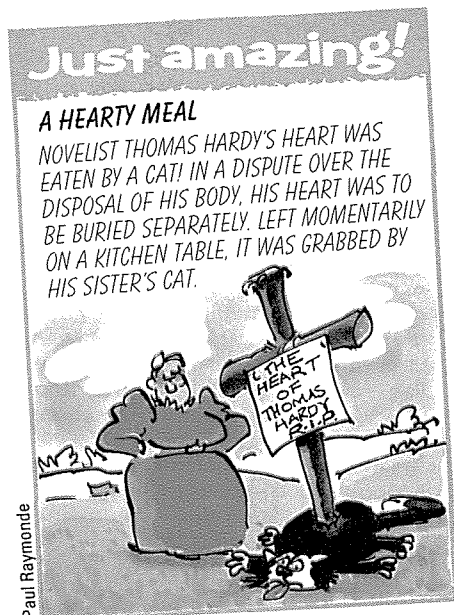
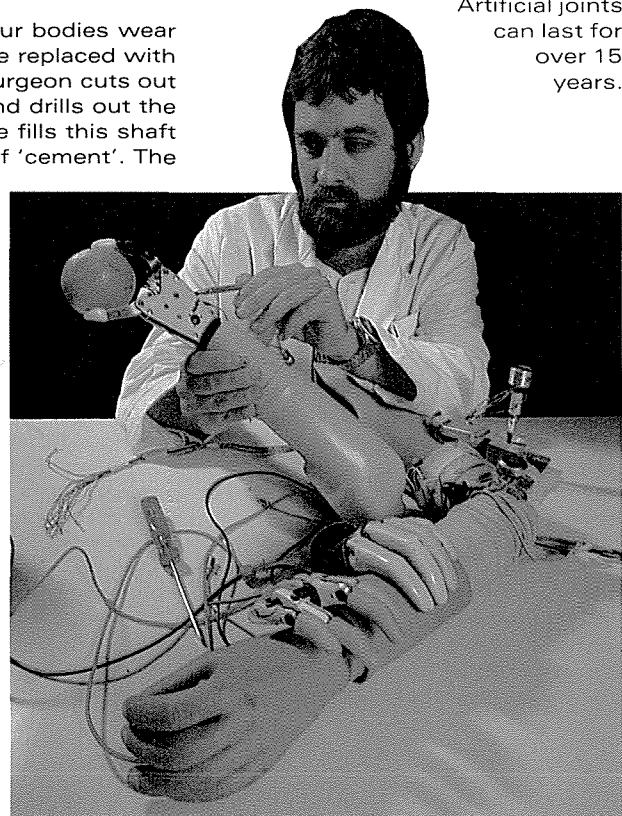


artificial joint is positioned with its anchoring pin down in the shaft.

Once the cement is set and the artificial joint is firmly fixed into position, full movement is restored.

Artificial joints can last for over 15 years.

Computer control is coming to artificial limbs. Nerve impulses in the remaining muscle tissues are detected and interpreted by the computer that, in turn, controls the movement of the artificial limb. Wearers sometimes say that it feels uncannily like their own limb.



- SCANNERS
- MEDICAL LASERS
- DIALYSIS MACHINES

ADVANCES IN PHYSICS AND engineering have helped modern medicine enormously, especially with machines for diagnosing and treating illness and injury. The first example of this 'new technology' was the X-ray machine.

X-rays were discovered by Wilhelm Roentgen in 1895, and so named because their nature was unknown. They pass through soft body tissues, but are absorbed by denser material. So when a beam of X-rays is passed through the body and on to a photographic plate, solid objects such as bone show up as negative images.

Ways with X-rays

Not only bones are X-rayed. By passing special dye-like substances into veins and arteries, the course and diameter of these structures can be determined. This is very important in disorders of the blood system. The same dye-like substance can be injected into joints to investigate their condition.

Since X-rays are blocked by metal objects, they are used to assess the results of hip replacement operations, because an artificial hip is made out of metal, normally titanium. They are also used to locate objects such as coins swallowed by mistake!

Imaging techniques

But X-rays are still restricted in their usage. An alternative technique for seeing inside the body is called Magnetic Resonance Imaging (MRI). The advantages of MRI are that it

Philippe Flailly/SPL

Medical Scanners

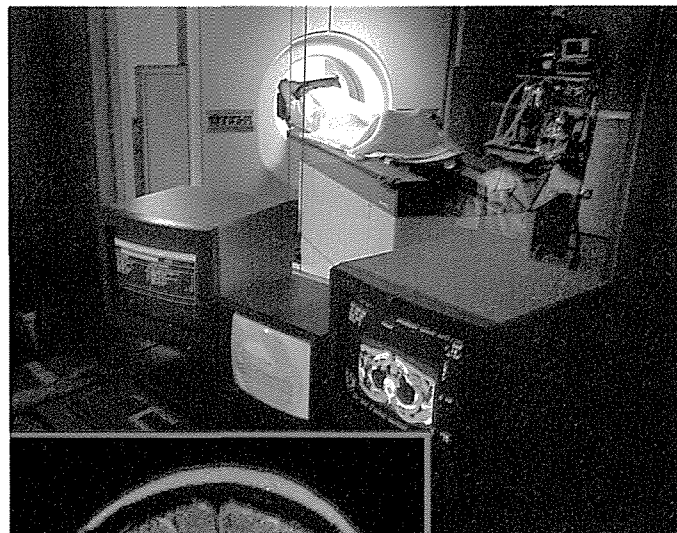
Positron Emission Tomography (PET) examines the brain using radioactive substances, which must be inhaled through a mask. It gives a highly detailed image.



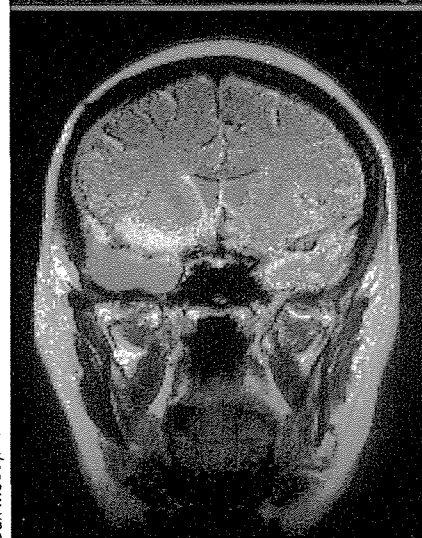
can produce clear pictures of soft tissues as well as bone, and there is no harmful radiation as it is based on magnetism and radio waves.

The MRI machine works by surrounding the patient with a powerful magnetic field. Soft body tissues contain many hydrogen atoms, which react to magnetism. When the protons in these hydrogen atoms are subject to a magnetic

Surgical gas lasers are used for delicate operations. The laser beam is produced in a gas-filled tube. An electric current is used to 'excite' the gases, producing a stream of photons, which are then directed by mirrors out of the laser.



Tony Stone Photo Library, London



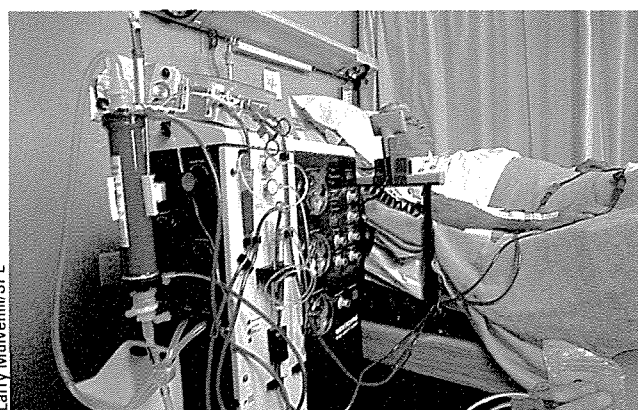
Dan McCoy/Rainbow

A brain scan is produced by Magnetic Resonance Imaging. The patient is placed inside a huge drum and surrounded by a magnetic field. When radio waves are applied, a detailed colour image shows up on the computer screens (above).

field, they start to spin in different directions – they are said to spin out of phase. A microwave generator is used to send out alternating radio frequencies, which make the protons 'flip' in and out of different energy levels. This in turn produces a detectable signal from the protons, which reflects the density of body tissue. When these complex signals are fed into a computer, a picture of the different densities can be made, producing a very clear and accurate image of the human body in cross-section.

CT scanners

Another type of scanner is the computerized tomography (CT) scanner. The machine works by calculating how much X-ray energy is needed to pass through the area being scanned, called the voxel. From this data, the machine produces picture elements (called pixels) on a television screen, just like on a home computer. Dense struc-



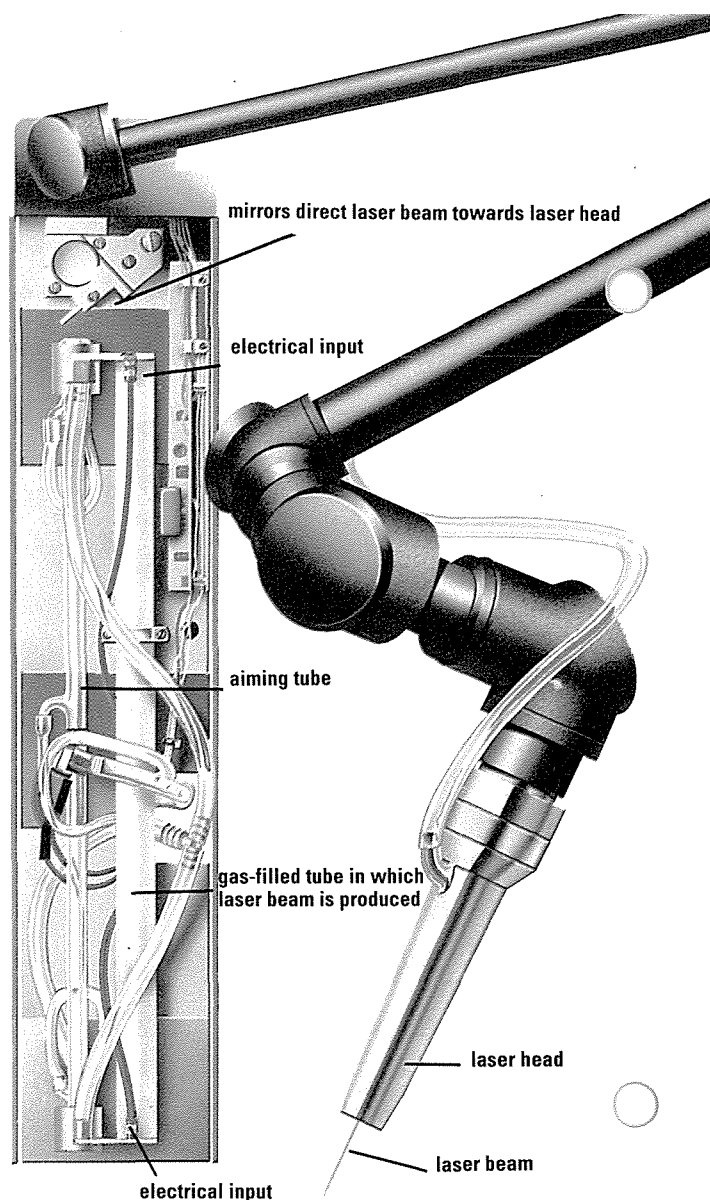
Larry Mulvehill/SPL

Kidney failure is no longer fatal, thanks to kidney dialysis machines – but these are large and expensive. In a newer method, (below) fluid is pumped into an abdominal cavity to cleanse the blood.

St Bartholomew's Hospital, London/SPL

tures such as bone appear white and air appears black, with the different organs coming out as shades of grey. The images are of better quality than X-rays, but not as good as the MRI pictures.

The newest imaging machine is called Positron Emission Tomography (PET). It works in a similar way to the CT scanner but the X-rays are released from a short-lived piece of radioactive material called a radionuclide. This very specialized piece of equipment is mainly used



electrical input

mirrors direct laser beam towards laser head

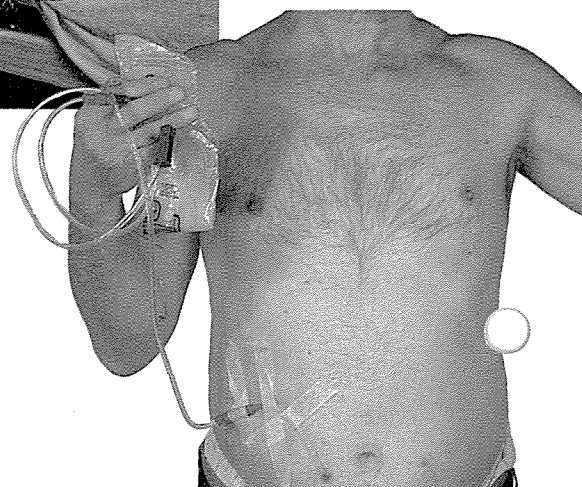
electrical input

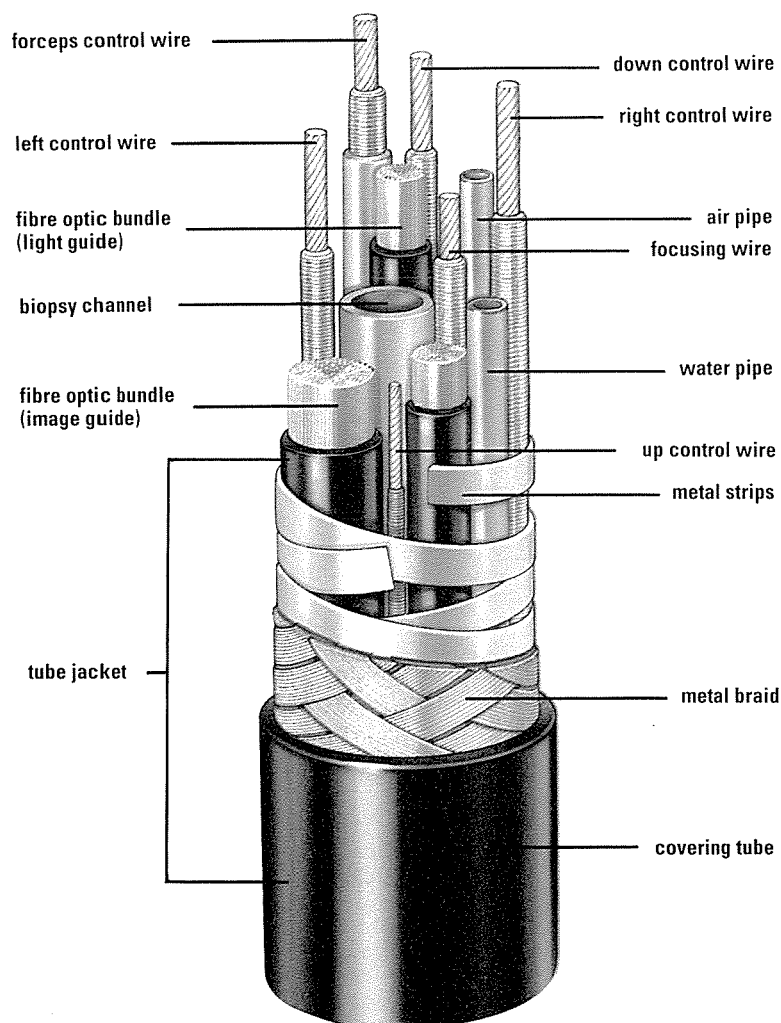
aiming tube

gas-filled tube in which laser beam is produced

laser head

laser beam





John Houghton

Endoscopes are used to explore inside the body and even perform surgery by remote control. The flexibility of the tube allows surgeons to 'see round corners'. The shaft contains fibre-optic bundles to illuminate and view the area to be explored, wires to control the instruments at the tip and pipes to carry air and water if necessary.

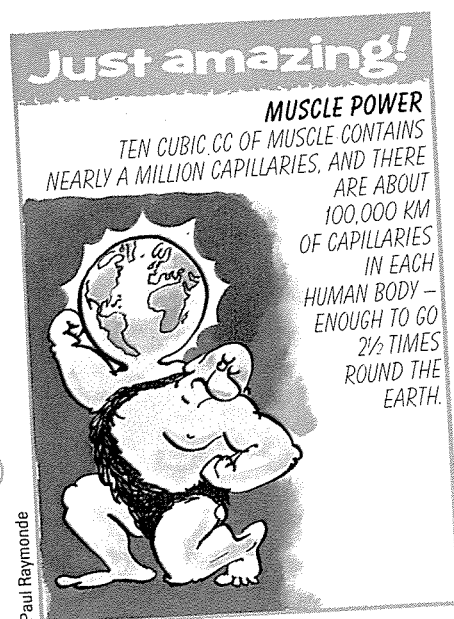
Digital Vascular Imaging (DVI) helps surgeons see the blood vessels they are operating on – and allows the patient to watch his own operation. The artery is injected with dye and X-rayed, so that it shows up clearly on the screen. The purple lines (below) are blood vessels.



Martin Dohrm/SPL

also used to treat damage to the retina of the eye (see 'Surgery Now', New Technology, pages 131–134). The mid-power He-Ne and GaAlAs lasers may be used to treat certain types of muscle and ligament injuries, as well as a wide variety of skin diseases.

Medical machines, such as the kidney dialysis machine, can now take over the functions of human organs. In patients with kidney disease, the normal filtering function of the kidney is lost and toxic waste products build up in the patient's blood, which can lead to death.



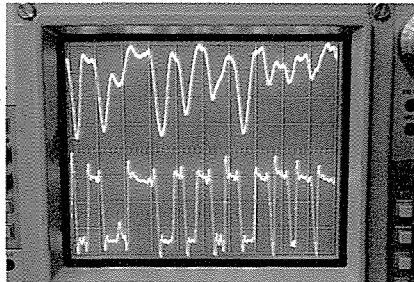
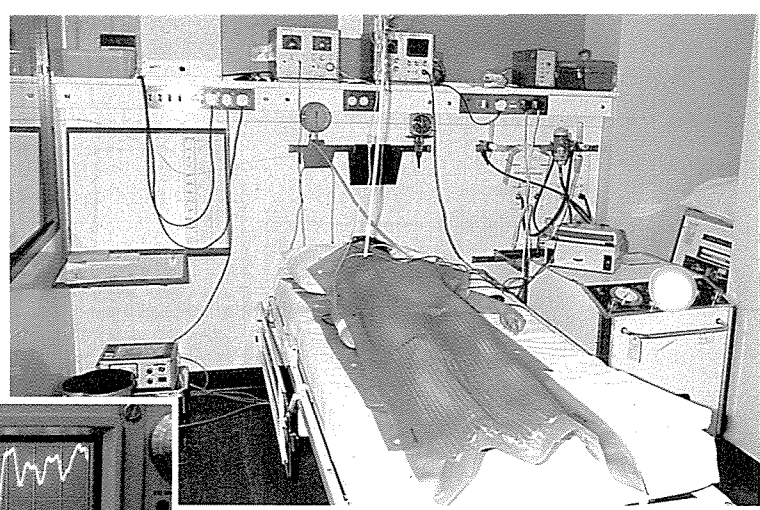
Paul Raymond

Dan McCoy/Rainbow



When kidney failure is diagnosed, the machine will keep the patient alive until a replacement kidney is found. Many patients live quite normally with regular trips to this 'dialysis' machine, which separates waste products from the blood. The machine is linked via a plastic tube to the radial artery in the patient's wrist. Blood passes along this tube to enter a part of the machine where the waste products are filtered out across a semi-permeable membrane. The

Life-support systems can keep patients alive for years after brain death occurs. An **electroencephalograph** (below) monitors any remaining activity and triggers the reflex responsible for breathing.



Tony Stone Photo Library, London

'cleansed' blood is then pumped back into the patient through a vein in the wrist. But if both kidneys are not working, the patient may have to undergo this process of dialysis by visiting a kidney machine two or three times a week. This is expensive and time-consuming, both for the patient and the hospital.



Portable dialysis

So scientists have devised a method of filling the peritoneal cavity in the abdomen with special dialysis fluid. The natural membranes of this cavity act like the semi-permeable membrane inside the kidney machine. They allow waste products to diffuse into the fluid, which is drained off after two hours, while the cleansed blood runs its natural course. This 'portable' dialysis machine is much

cheaper and simpler than a kidney machine.

Another life-saving machine is the 'heart-lung machine' used during heart transplant operations. When the heart is removed, the blood circulation must be maintained or the brain will quickly die from oxygen starvation. The kidneys also need plenty of blood to keep them functioning correctly. So a heart-lung machine takes over the functions of the lungs and heart.



Capillary action

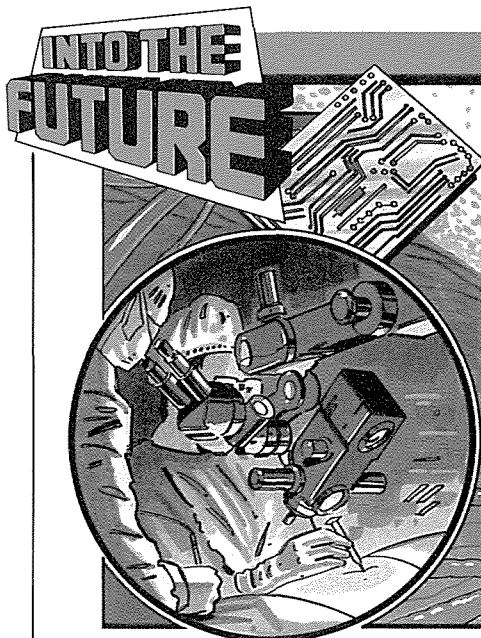
The lungs contain blood vessels, called capillaries, with very thin walls. Oxygen diffuses through them into the blood supply, and is then transported around the body.

The heart-lung machine, instead of having blood vessels, has tubes with semi-permeable membranes, which allow oxygen to diffuse into the blood and carbon dioxide to diffuse out. It also has a pump to take over the heart's function.

When the machine is connected, it bypasses the heart and lungs until the new heart is working.

Biophoto Associates/SPL

The heart and lung machine takes over the functions of those two organs during heart transplants, keeping blood flowing around the body.



NOT TOO HARD TO SWALLOW

▲ Once inside the patient, the video camera pill will travel around the body under its own power, through the digestive system or the blood vessels.

▲ Having found the trouble spot, the camera will show the problem on a monitor screen to a doctor. Advanced versions will be controllable to perform surgery on site.

MOST FICTIONAL ROBOTS are depicted as mechanical people, with almost human qualities — think of C3PO or R2D2 from *Star Wars*, or *RoboCop*. But today's robots usually bear no resemblance to any human form at all.

It was the Czechoslovakian author, Karel Capek, who coined the word 'robot' (from the Czech word 'robota' meaning slavework) in his 1920 play *RUR*. He conjured visions of humanoid machines carrying out everyday duties. But today, by far the most common robots are the industrial kind, playing a vital role, for example, in car assembly plants around the world.

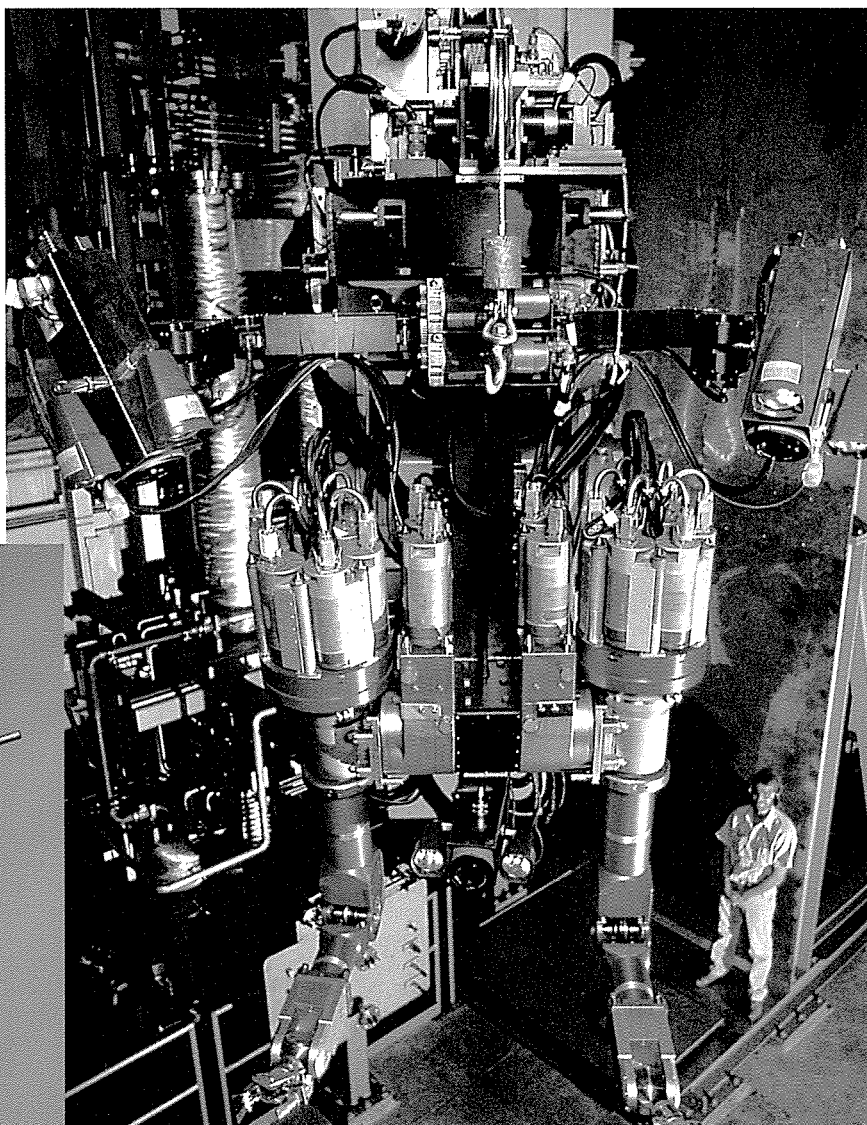
Japan alone employs over 150,000 robots in manufacturing. Most are robot arms that weld, put together, and spray-paint the components for new cars and other mass-produced goods. Robots are rapidly taking over those jobs that human workers find either boring or dangerous.

Computer-controlled

At the heart of each robot, controlling its every action, is a small computer. Before the robot can do anything at all, its computer brain must be given precise details on how to perform the given task.

Claude Charlier/SPL

ROBOTICS



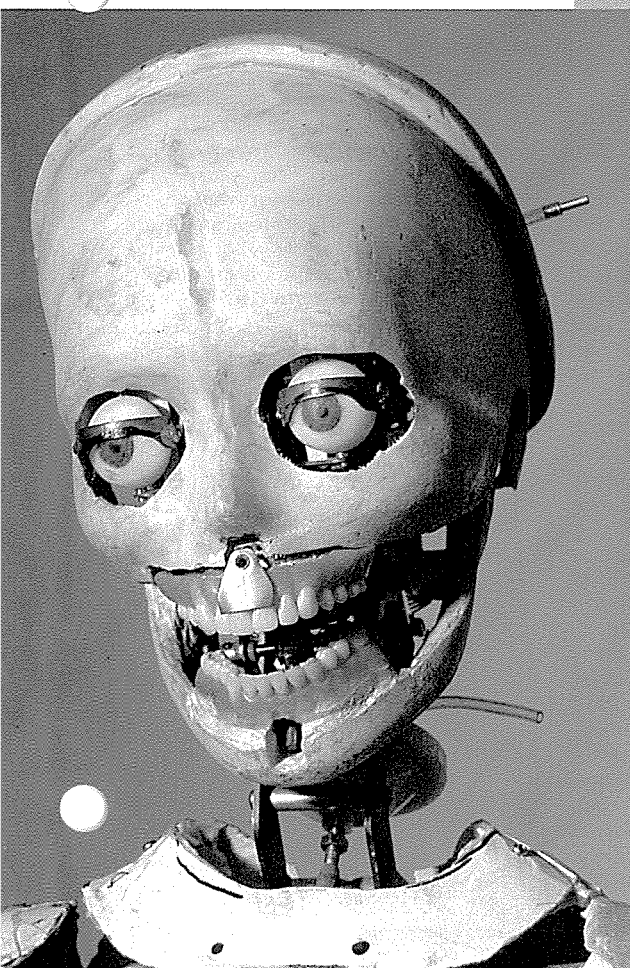
Hank Morgan/SPL

The advanced servomanipulator is a huge industrial robot equipped with video vision that can be operated by remote control. It is used at the Oak Ridge nuclear installation in the USA.

An android is a robot that looks like a human being. This 'smiling' android was built by Mr Mizuno of Japan, who specializes in designing and building robots which resemble the famous.

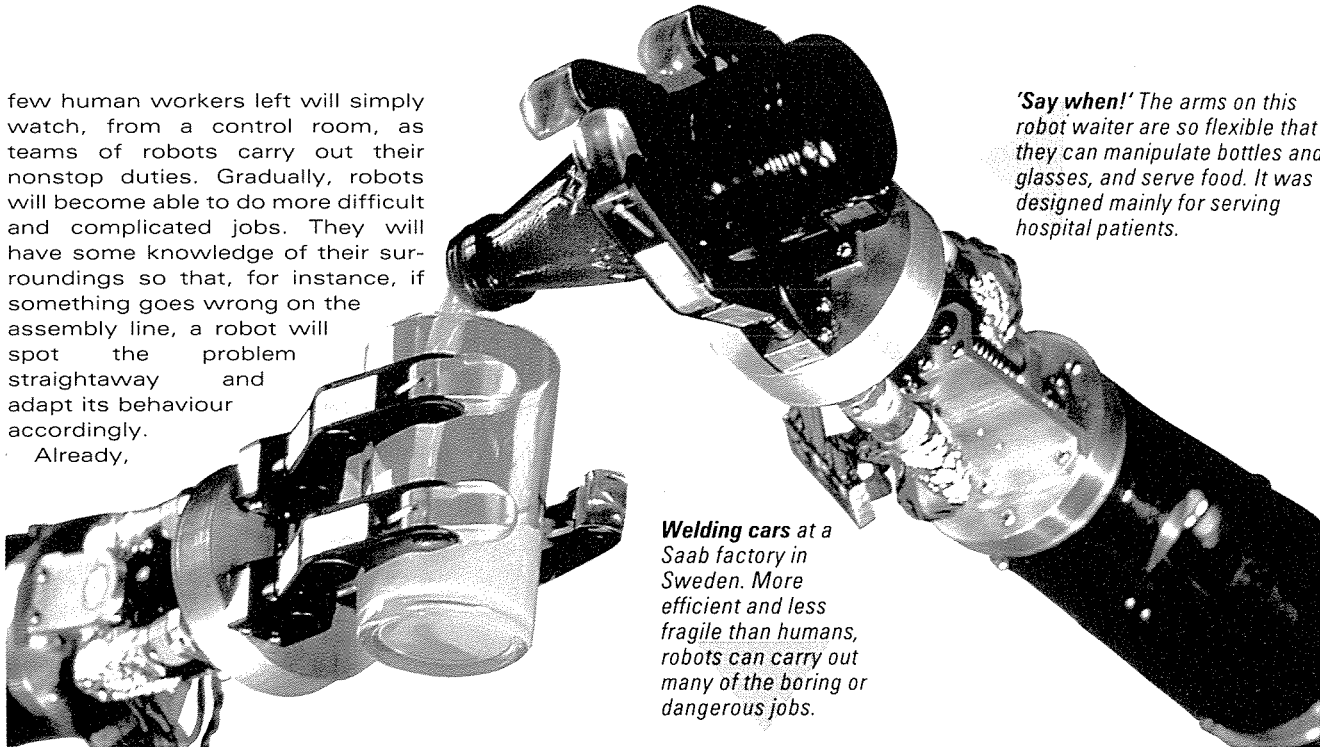
Typically, a human 'teacher' guides the robot by hand through all the actions it has to carry out. These actions are then automatically stored as a list of commands in the robot's computer. From that time on, the robot will repeat the actions exactly, over and over again, under computer control. It can be switched to a new job by giving it a new program and, if needed, a new tool for its arm.

In the future, many factories will have hardly any people in them. The



few human workers left will simply watch, from a control room, as teams of robots carry out their nonstop duties. Gradually, robots will become able to do more difficult and complicated jobs. They will have some knowledge of their surroundings so that, for instance, if something goes wrong on the assembly line, a robot will spot the problem straightaway and adapt its behaviour accordingly.

Already,



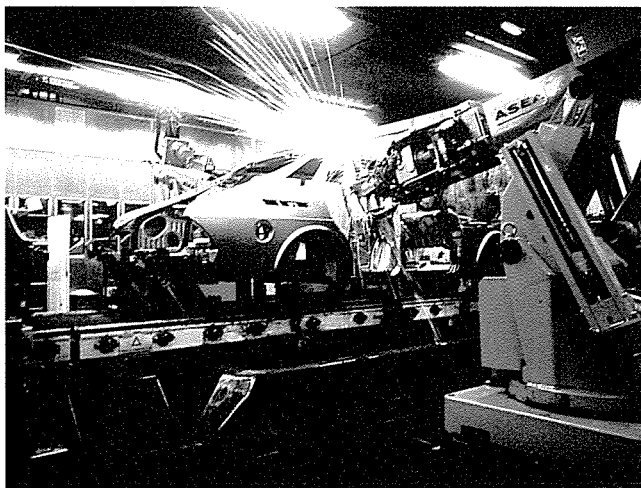
'Say when!' The arms on this robot waiter are so flexible that they can manipulate bottles and glasses, and serve food. It was designed mainly for serving hospital patients.

Welding cars at a Saab factory in Sweden. More efficient and less fragile than humans, robots can carry out many of the boring or dangerous jobs.

Tadanori Saito/SPL

Look, no hands! At Rover's car plant in Longbridge, UK, robots shape and assemble engine parts. They take in raw metal castings, machine them to the required shape and assemble them.

The components are transported by Automatic Guided Vehicles (AGVs) – these follow underfloor cables and are controlled by a supervisory computer.



Saab-Scania/SPL

robots will not become a practical proposition until next century.

By then, intelligent robots will roam across the ocean beds in search of valuable minerals. Others may be at work in nuclear power stations, handling radioactive substances, and doing other hazardous jobs like fire-fighting.

Artificial people

Science fiction writers predict that in the future, robots may be built that look and act almost the same as humans do. Called androids, these artificial people might eventually work and live among us as equals. There could even be a 'bill of rights' protecting the interests of robots and a law to stop any android from being disconnected.

The use of more intelligent, or 'smart', computers will greatly improve the performance of space probes. As the distance from Earth

robots with camera 'eyes' are being taught to recognize objects in the real world – even objects that are tilted, partly hidden, or at different distances. As humans, we take this ability for granted because our brains are so incredibly good at making sense of what we see. In robots, though, it means matching the appearance of the scene picked up by its TV camera with the appearance of known objects stored in its memory.

Home helps

With improved senses and a more 'intelligent' electronic brain, experimental robots are able to do useful chores around the home – a dream of science-fiction writers for over 50 years. Dusting or washing dishes hardly seem like complex tasks. But try to describe them in detail to a machine and you find that they are made up of thousands and thousands of tiny separate steps. Also, the tasks may change slightly from day to day. Different dishes need washing, or toys need moving before the carpet can be vacuumed. For these reasons, practical home

Just amazing!

MACHINE MADNESS

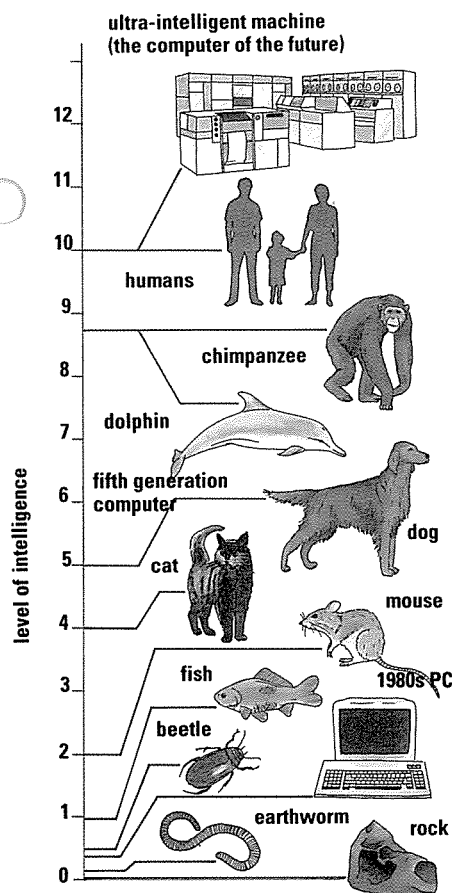
IN 1985, A ROBOT WAITER CALLED DONIC RAN AMOK IN AN EDINBURGH RESTAURANT. AFTER SPILLING WINE AND KNOCKING OVER FURNITURE, ITS HEAD FELL OFF INTO A CUSTOMER'S LAP!



Paul Raymond

Rover Group





Android version of the Beatles, at the Rock Circus in London. All of the models are controlled by computers.

Brain power. This table shows the intelligence levels of man, machine and animals. The numbers on the scale are not IQ values but are intended to give the relative brain power of each category.



Rock Circus

increases, it takes longer and longer for radio signals to travel to a probe from mission control. The use of smart computers will enable probes to carry out complex investigations, making on-the-spot decisions as conditions change.

Smart computers will be installed in the robot vehicles being designed to explore Mars early next century.

But while robots become more and more like their human creators, there is still a major stumbling

block, which is proving difficult to overcome. Computers do not 'speak' or understand human languages. They have to be given instructions in special programming languages that are very different from, for example, English. Teaching them to understand the sort of natural language by which humans normally communicate is an incredibly difficult task.

Voice synthesizers

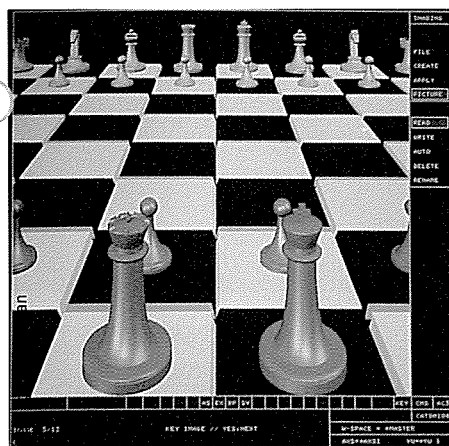
For some years now, even small computers built into educational toys have been able to synthesize normal speech from electronically stored sounds. But the reverse process of voice analysis is very much harder to achieve. To start with, no-one speaks in exactly the same way. Even when speaking the same word, each of us makes a slightly different pattern of sound waves in the air.

On top of this, there are the complexities of human language itself. For instance, in the three sentences, 'Go right to the top', 'Move your right hand', and 'I think you are right', the word 'right' is used in a completely different way each time. We understand this because of the context in which 'right' is used. But how is a computer supposed to know? There are thousands of other ambiguities like this in English, and in other languages, which a computer has to be made aware of before it can properly analyse speech.

Translating machines

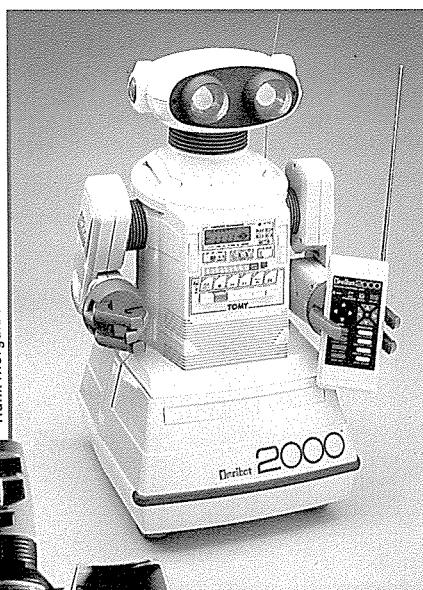
At present, computers using even the best voice-analysis programs only work if they are spoken to slowly, clearly, and using just those words that the computer has been taught to recognize. In Japan, for example, a translation machine called Atlas has been developed by Fujitsu that can convert 4,000 Japanese spoken words into English. The company is also working on a system that recognises continuous speech with different pronunciations and speeds. In Britain,

Computer chess games are now able to beat human grandmasters. The top computers calculate nearly one million moves per second.

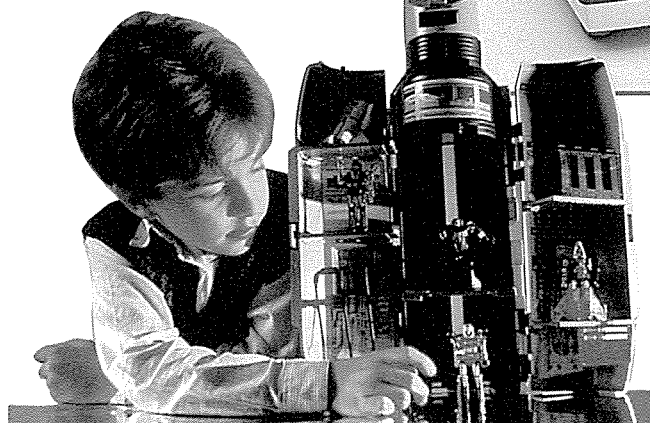


Robot toys are as popular as the real thing. Just as industrial robots have become more sophisticated every year, so too have the toy versions.

Hank Morgan/SPL



Robot teachers can be fun. Omnitot 2000 has been used in schools and by the UK's Department of Transport to teach children about road safety. Commands can be sent up to 20 metres by remote control.





Logica and British Telecom are experimenting with a railway timetable that gives information over the phone. The system, known as Vodis, asks callers to repeat themselves if it cannot understand what has been said.

Intelligence

Today's brightest computers certainly fall well short of the average dog or cat in terms of intelligence. They may calculate millions of times faster than us, but in most other respects they are still surprisingly stupid! However, new ways of programming are being developed to boost artificial intelligence.

Computers can now be fed with rules of thumb, known as heuristics. In other words, the computer can make use of tips and advice from a human specialist covering some particular area of knowledge. The resulting 'expert system' can aid doctors, for instance, in identifying certain, less common kinds of

Voice analysis is one of the last barriers to more human-like robots. Much research is going on into voice-recognition systems.

Arc welding by robot is far more precise than human handiwork. This computer-controlled robot is welding a car exhaust.

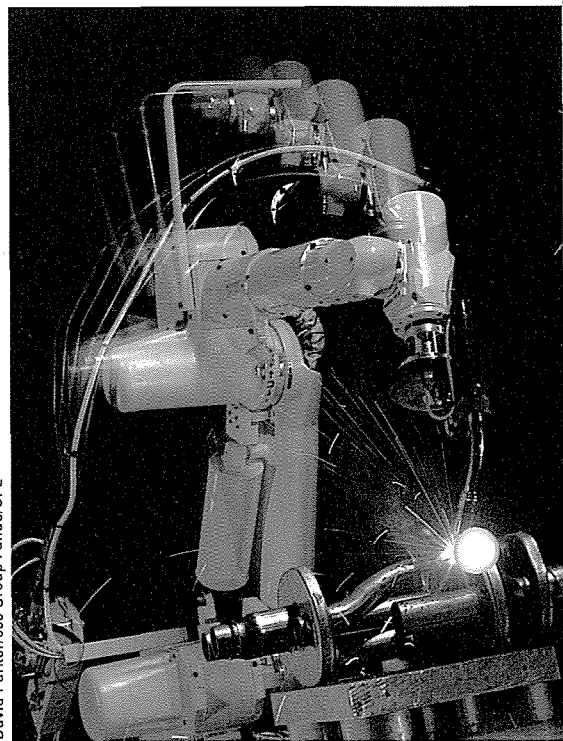
illness or in selecting medicines.

Other expert systems are helping in the search for oil and valuable minerals, or even in the design of new computers. In November 1988, a computer called *Deep Thought* became the first machine to beat a human grandmaster in a chess tournament. The most modern chess playing robot can select the perfect move by searching over one million each second.

Yet, expert systems have proved less of a breakthrough than originally expected because they simply regurgitate the knowledge fed into them. Future intelligent machines

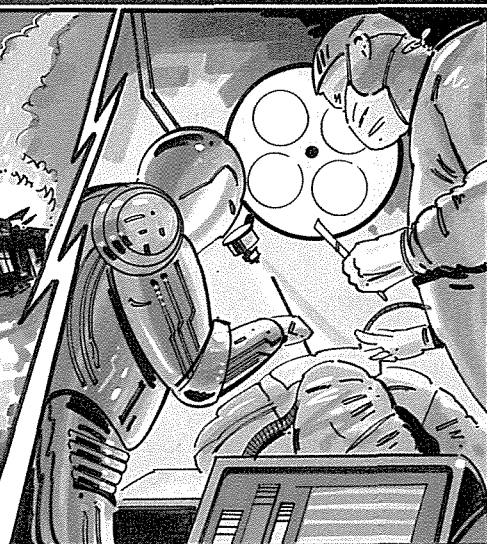
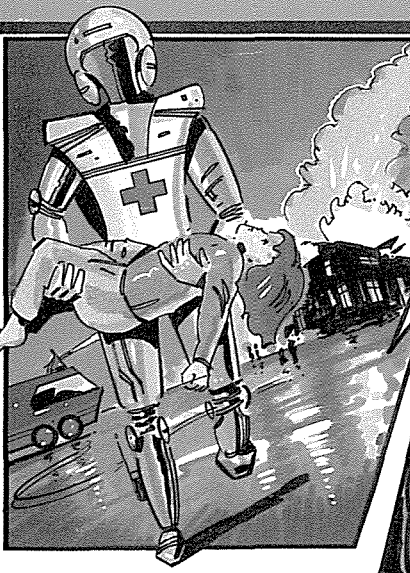
will be able to learn from past experience, remembering their mistakes so that their performance gets better as time goes on.

One very promising approach being studied now is to build electronic circuits that mimic the way our own brains work. A so-called 'neural computer' will be able to try out different connections in a network of artificial brain cells until it settles on one that calculates the right answer. In areas like understanding human speech and recognizing images, neural computers will be much more adept than even the most powerful computer today.



David Parker/600 Group Fanuc/SPL

INTO THE FUTURE



ROBOTS ARE GO!

▲ As robots become more advanced, they will be able to perform household chores, such as Hoovering, washing-up and mowing the lawn.

▲ But robots will also have more important functions with the emergency services, such as fighting fires, defusing bombs, or even carrying out rescues.

▲ Robots will also be able to perform some types of surgery with great precision – although still under human supervision.

- TYPES OF MEMORY
- BACK-UP SYSTEMS
- OPTICAL STORAGE

A SPECTACULAR ADVANCE in computers has been the size and speed of their memories. If cars had progressed as much as computers over the last 40 years, then a car today would cost less than 10 pence, go 500,000 km on a litre of petrol and travel at five times the speed of sound.

The memory of a computer stores data and program instructions — information the computer needs to do calculations and other tasks. There is an internal memory and an external memory.

The internal memory is like the shelves in a department store, holding items that can quickly be taken out or put back. The external memory — also called a store or storage device — is more like a warehouse. It can retain a much greater amount of information.

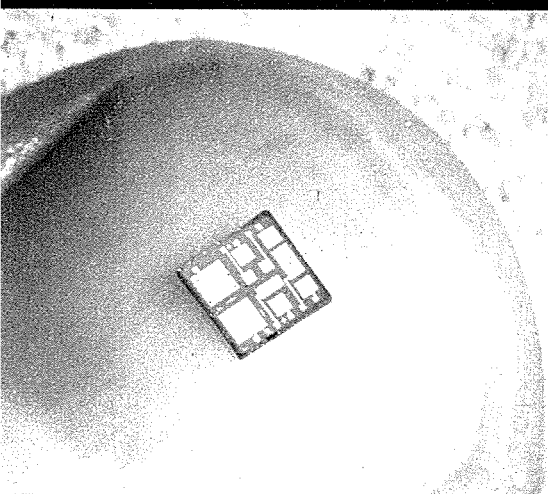
Bits 'n' bytes

Every number, letter or other symbol 'known' to the computer is represented as a 'byte' — a code made up of eight elements or 'bits'. The word 'bits' comes from *binary* digits, because binary is the arithmetic used to program computers. In binary there are two digits — 0 and 1.

A computer's internal memory is in the form of chips — silicon wafers etched with electronic circuits and encased in plastic. Internal memory can be either RAM (Random Access Memory) or ROM (Read Only Memory).

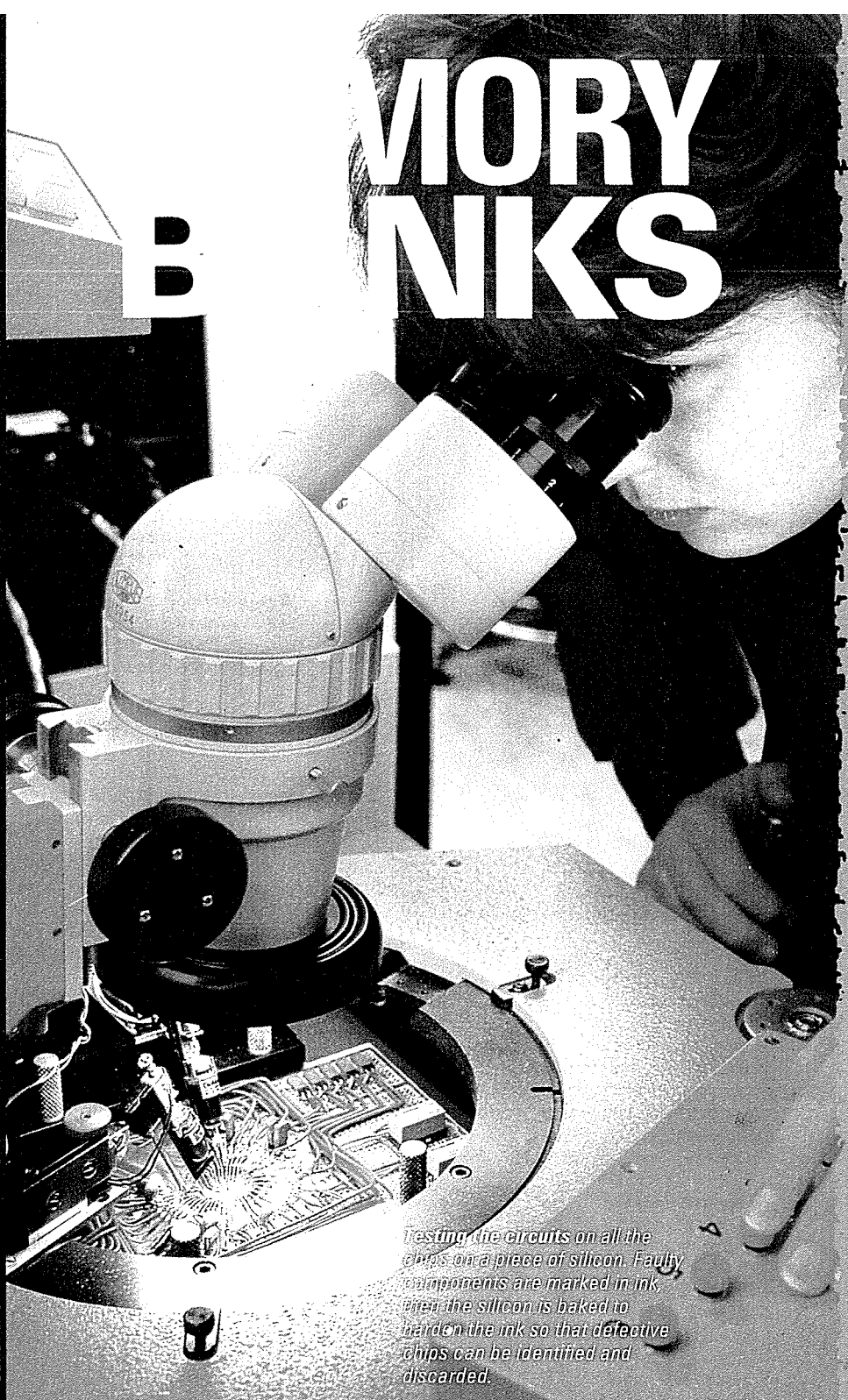
Any programs or data you enter at a keyboard are stored in RAM. You can put information into RAM 'write to it' or find out what is in it

SPL



Too small to handle — this minuscule chip has been tested and is ready to have its connections soldered on before being enclosed in plastic.

MEMORY BANKS



David Parker/SPL

Testing the circuits on all the chips on a piece of silicon. Faulty components are marked in ink when the silicon is baked to harden the ink so that defective chips can be identified and discarded.

COMPUTERSPEAK — LANGUAGE OF THE FUTURE

BASIC: one of the 'languages' used to give instructions to computers. It comes from **B**eginners' **A**ll-purpose **S**ymbolic **I**nstruction **C**ode.

binary: a number system based on the two digits 0 and 1 (equivalent to the 'off' and 'on' of electronic circuits)

bugs: errors in a program

disc (disk): plastic or aluminium platter with magnetic coating on which data are recorded

hardware: the physical parts of your computer

hex: short for 'hexadecimal' — a number system based on the digits 0 to 9 and the

letters A to F

interface: an electronic circuit with connecting leads and plugs for linking peripherals, such as printers and disc drives, to a computer

IT: short for Information Technology

K: short for 'kilo' (1000)

peripheral: any device you connect to a computer, such as a printer.

program: step-by-step instructions that a computer follows to solve problems

software: programs or instructions that tell your computer what to do

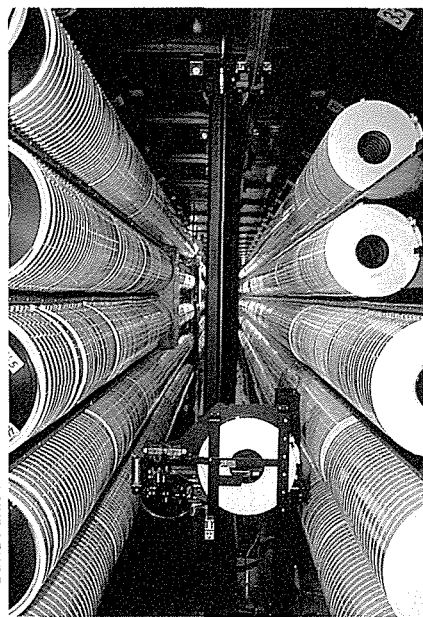
VDU: monitor or TV screen — from **V**isual **D**isplay **U**nit



'read it', and you can change the contents. Information the computer needs to carry out your instructions is stored on ROM chips.

Built-in programs

For example, a program on ROM instructs the computer to print letter 'A' on the screen when you press the 'A' key, and graphics software lets you draw pictures on the screen. These programs are



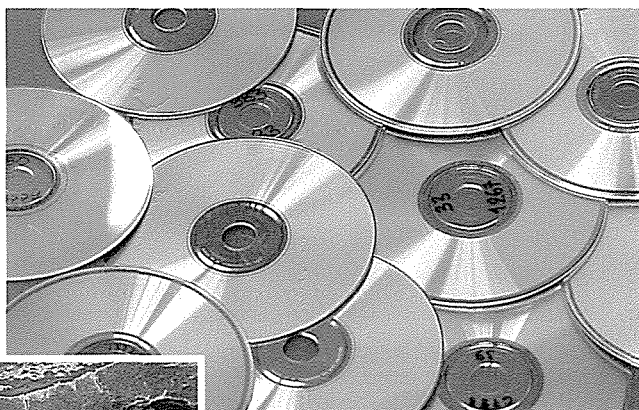
David Parker/SPL

Chris Lyon

built into the computer at the factory. You can read them (which you do when you use them) any number of times, but you cannot alter their contents. This is important as the internal programmes are extremely complex. If a single digit is changed by accident, the entire programme is disabled.

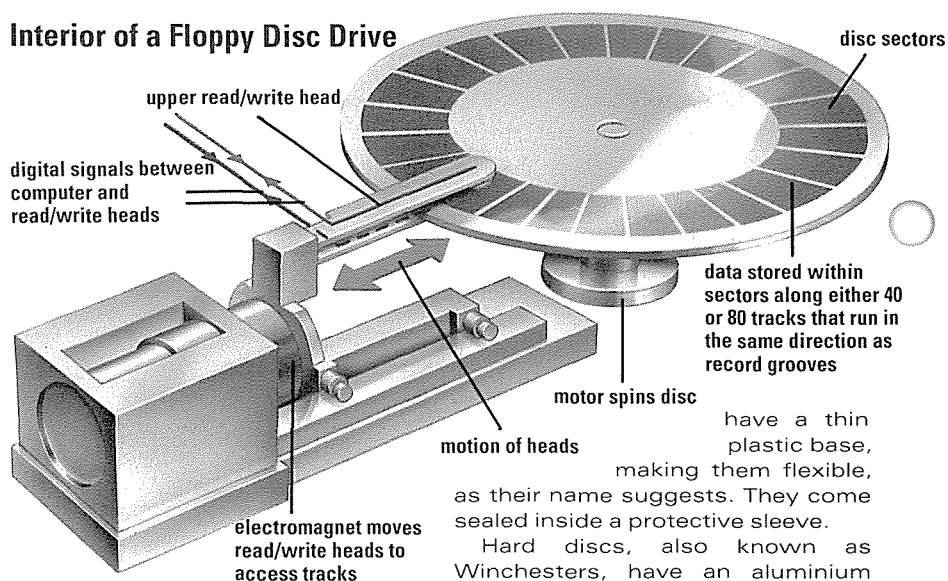
Every year, chip manufacturers

Compact discs like those used for music recordings are being developed for storing computer data because they have a very large storage capacity. They store data as tiny surface pits and blanks (below).



Etienne Poupinet/Jerrican

Interior of a Floppy Disc Drive



A floppy-disc drive spins the discs like an audio turntable and records data in sectors and tracks. An index hole in the disc marks the start.

An automated library of computer tapes at the Fermi Laboratory in the USA. A robot finds the required tapes and files them again after use.

squeeze more and more storage capacity on to each RAM chip. Today's personal computers use either 1, 4 or 8 megabyte RAM chips. RAM capacity is increased by installing sets of chips side by side.

No room

Even a million bytes of RAM are not enough for some computing tasks. And there is the added problem that all of the information stored on RAM disappears if the power is

Pits and blanks

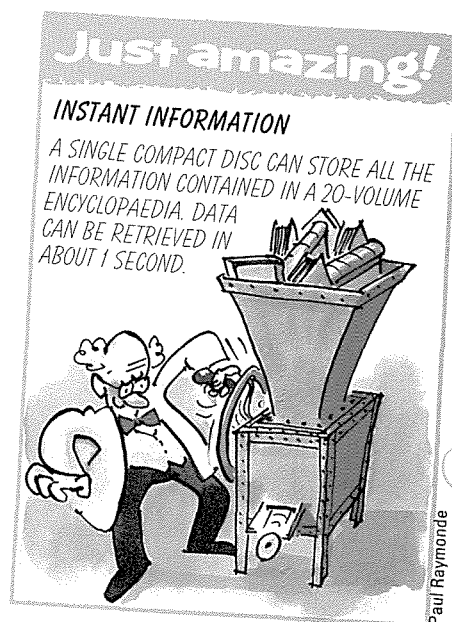
An alternative computer external storage medium is provided by compact discs (CDs) — as used for music recordings. CDs store digital information in the form of tiny pits and blanks on the shiny surface of 12-cm metal discs. By scanning the mirror-like surface, a laser beam can extract the coded information from it at great speed.

Erasable discs

One of the drawbacks of early compact discs is that, once written on, they cannot be erased and overwritten. But read/write discs are now available. Also, a new kind of optical disc is being developed which will be erasable, so you can write on it, erase and rewrite again and again.

turned off. This is the reason computers are equipped with external storage devices, such as disc drives.

Disc drives store data on magnetic discs as strings of north and south poles. Discs come in two forms: floppy and hard. Both have a magnetic coating similar to that of an ordinary cassette tape, and spin around rapidly beneath the recording head of a disc drive. Floppies



Sci-fi worlds can be speedily created by computer graphics systems (including paintbox and 3D solid modelling systems).

VIDEO ART

- HI-TECH GRAPHICS
- PICTURE ELEMENTS
- SYNTHESIZERS

WHAT DO GHOSTBUSTERS, *Return of the Jedi* and *Tron* all have in common? The answer is that each of these blockbuster films includes scenes that a computer helped to create. What's more, the computer-generated action looks so convincing that it fits in perfectly with the rest of the movie!

Powerful computers and advanced programming techniques have been combined to produce some amazing graphic effects. Pictures emerging from today's computers can be as clear as a photograph and nearly lifelike in appearance. The computer can draw any object or scene, no matter how fantastic.

Twenty minutes of the film *The Last Starfighter* were produced en-

tirely on one of the fastest computers in the world. Those 20 minutes of computer animation show a rocket-powered car blasting off from Earth, then soaring through the clouds and out into space. They show battling starships and strange alien planets. To produce these special effects using hand-crafted models would have cost between £7-14 million. But with the aid of a supercomputer, these thrilling action scenes were made for just over £2 million.



Pixels and rasters

The commonest way to show computer-generated pictures is with a special graphics monitor. The computer divides the monitor screen into a patchwork of dots or pixels (short for 'picture elements'). Then it decides which of these pixels should be turned on or off at any given moment. The complete pattern of pixels on the screen is known as a raster.

About 30 times a second, all the pixels in the raster are redrawn.

That way, the screen display never fades or flickers. A beam redraws the raster each time, starting at the upper left-hand corner of the screen, darting rapidly along a zig-zag track and ending at the right-hand corner. Then the beam races back along the shortest possible path to its starting point, to begin its split-second journey all over again.



Special effects

The more pixels there are on the screen, the sharper the resulting graphics image. But just how many pixels can a computer handle? That depends on the computer's size and speed. The brightness and colour of each pixel is managed by a small chunk of the computer's memory. So, to handle more picture elements you need a computer with a larger memory. And if you want the picture to change quickly or in a complicated way, the computer must also be able to work at high speed.

Another classic film featuring



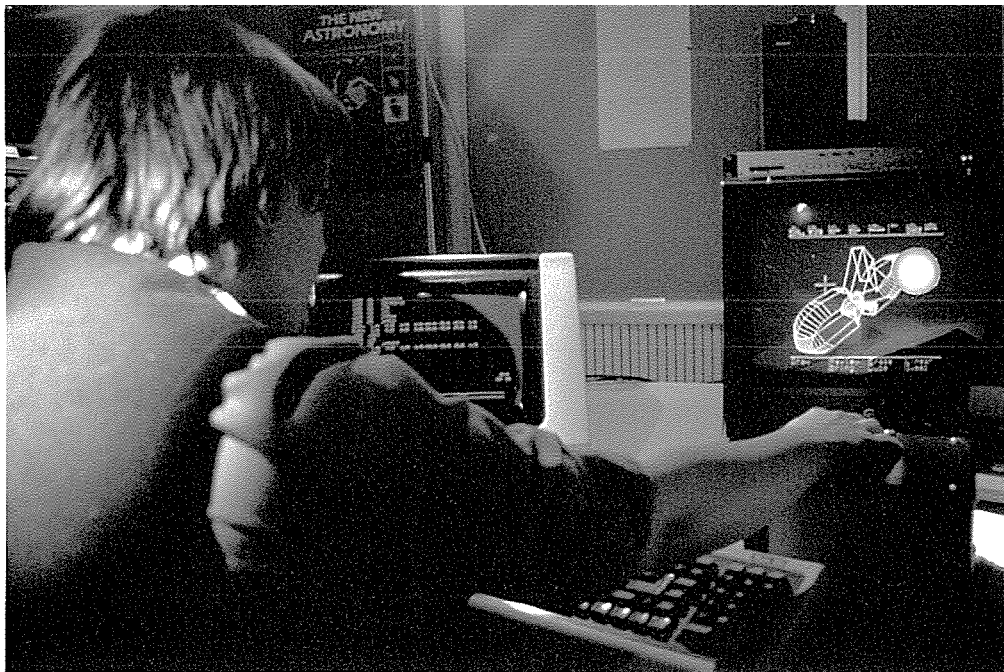
Computer graphics is Clarke's *2010*, in which much of the action takes place near the planet Jupiter. Filming on location would have posed quite a problem for the film's producers! So instead they turned to a Cray supercomputer to depict what Jupiter might look like from a passing spacecraft. Starting with actual photos of Jupiter taken by the Voyager probes, the filmmakers used the Cray to add extra colour, detail and cloud movements. Several trillion calculations had to be carried out for each second of finished film and, when complete, *2010* included 130 seconds of Jupiter animation.



Ray tracing

Over £1 billion a year is now spent on computer graphics for film and television, world-wide. Compu-

Dr Seth Shostak/SPL



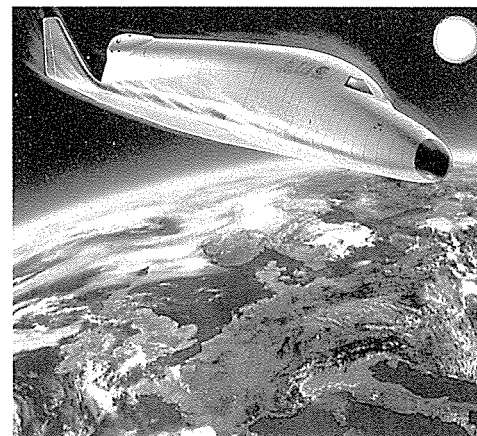
Creating '3D' animation for television. A video camera (1) shoots a picture placed on the video rostrum (2) so that it can be stored in digital form. The picture, now on the visual display unit of a computer graphics system (3), is altered and reconstructed as desired by a designer using the stylus on the digit-pad (4). The graphics system is controlled by software programs in a computer (5). The video tape recorder (6) records a series of single frames of the image for playing back as an animated sequence on the television screen.

The new 'designer-friendly' computer graphic systems can be operated with no previous knowledge of programming.

ter-generated special effects can be intermixed with live action so well that the viewers simply can't tell the difference.

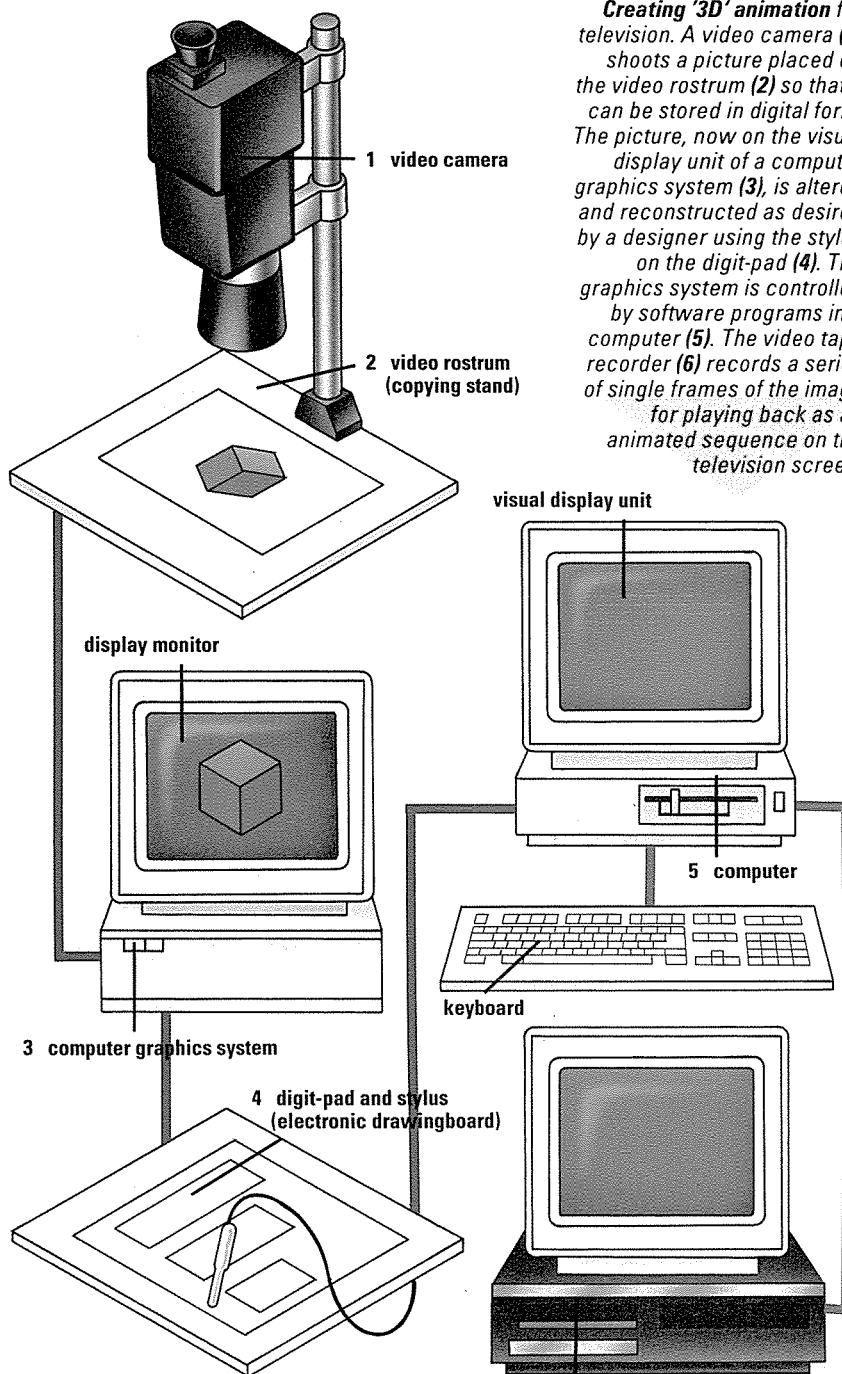
Using the latest graphics programs, lifelike textures and shading

ON-SCREEN ART



Computer graphics generally have a smooth and regular quality. But patterns found in nature, such as a coastline, or the surface of a mountain, are usually rough, uneven and irregular. Dr Benoit Mandelbrot, a mathematician, has identified shapes that he has called 'fractals' (from the Latin word fractus meaning broken): curves with branches, which link together to form irregular lines. One use of fractals is to create highly detailed geometrical patterns. Another is to create a landscape – the artist programs a computer with fractal formulas that will throw up a variety of semi-random structures, which are ideal for depicting, say, the shore of an island, the course of a river or even the Earth's surface as depicted above. From these the artist can elect the one that is just right.

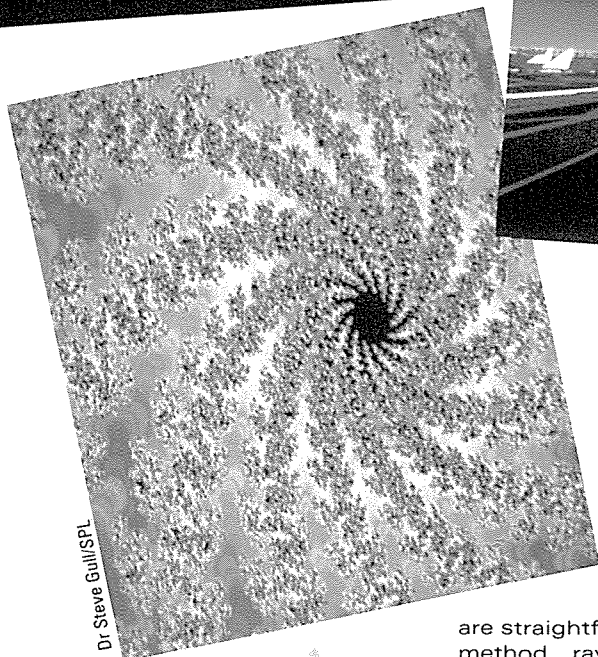
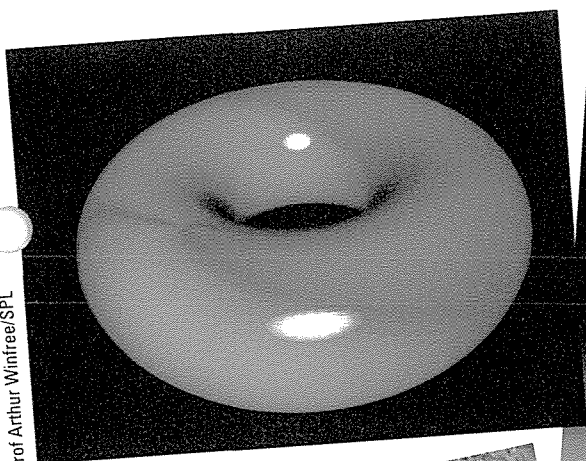
Ducros/Jerrican



6 television and video tape recorder

Mark Franklin





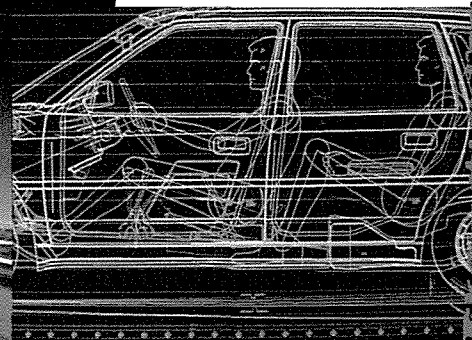
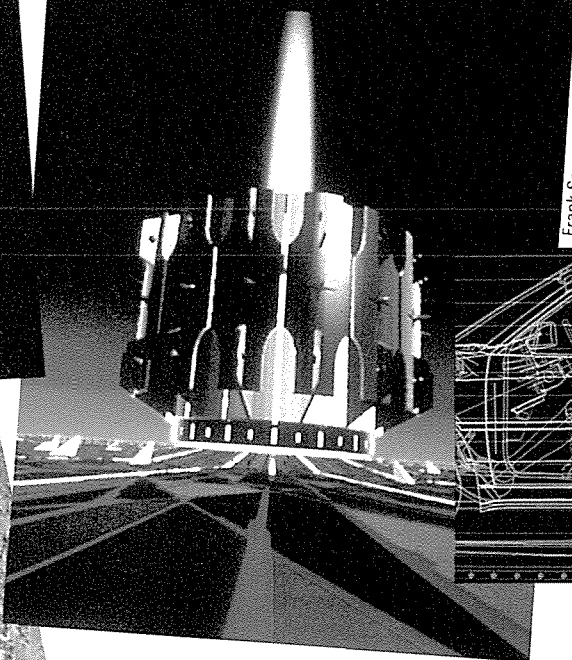
Images can be created with computer graphics that vary from smooth three-dimensional curves (top) to complex geometrical patterns (above).

are straightforward to produce. One method, ray tracing, lets rays of light bounce off (or pass through) the surface of objects in the computer graphic just as they would off real objects.

Computer graphics are extensively used on television. One feature

A graphics system with very high resolution output – 800 lines per centimetre on the screen, for example – can produce a very sharp image.

Engineers use computer graphics to check calculations on how parts of a new product, such as a car, might perform.



now in common use is digital television picture manipulation, using systems such as Quantel Graphics Paintbox. A moving television picture is reduced, enlarged, flipped (turned over), overlapped, merged, folded, exploded, dissolved and distorted in a sequence controlled by a computer program. Graphics displays at the beginning of television programmes are often produced in this way.



The computer-scope

High-performance computer graphics are also finding a multitude of practical uses in science and industry. Through them, researchers can investigate, for instance, how new chemicals and drugs will work.

In effect, the computer becomes an enormously powerful microscope. It shows by detailed moving pictures how the individual molecules (the tiny 'building blocks') of a new drug, for example, join up like a key in a lock with other molecules inside a person's body. Hoping to find a key that will work even better, the researcher can try a drug with a slightly different molecular structure. 'Another look through the 'computer-scope' then shows what the effect of the change has been.



Simulators

A special kind of computer employs graphics to help train aircraft pilots. Called a flight simulator, it is connected with all of the instruments in a mock-up of the plane's cockpit. The 'windows' in front of the trainee pilot are actually large display screens on which the computer recreates the view, from instant to instant, that the pilot would get if it were a real plane in flight. Accurate details of the runway layout of dozens of major airports around the world may be stored in the simula-

The Fairlight CMI (Computer Musical Instrument) is one of the best synthesizers in the world. You can draw the exact waveform you want directly on to the computer screen using a light pen. Unlike many other synthesizers, instructions are entered through an alphabetical and numerical keyboard.



tor's memory. To add to the illusion, simulated flights can take place by day or night, and in clear weather or fog.

Keeping time

In a small room at the Media Laboratory in Cambridge, Massachusetts, USA, two people, a violinist and a flautist, play while a third conducts. The accompanying melody of another instrument, such as a harpsichord, comes from a computer-controlled synthesizer that has been programmed with all the details of the musical piece it has to play. But how does the synthesizer manage to keep in perfect time with its human counterparts?

The secret lies in a special device that follows the movement of the conductor's baton. This device passes on all the information on timing that the computer needs so that it can 'play' the synthesizer. Using such equipment, orchestras of the

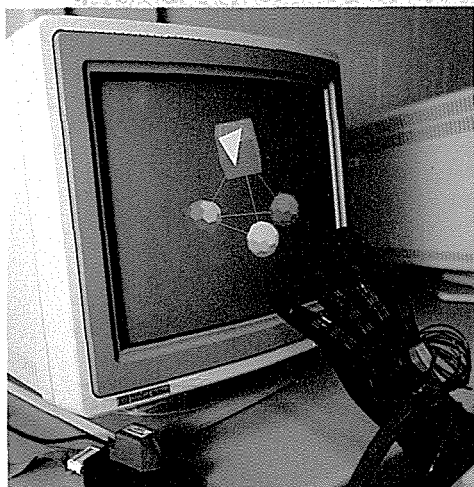
Rediffusion Simulation



Flight simulators can be incredibly realistic. Looking through the 'windows' of the cockpit – actually screens showing computer graphics – the pilot even has the chance to react to animated images of other aircraft, both on the ground and in the air (right). In addition to helping pilots learn flying techniques, flight simulators are very useful when a pilot has to get used to a new type of aircraft.



MOVING PICTURES



Wearing a Dataglove, you can 'grip' three-dimensional objects on a computer screen, lift them, move them around and even throw them so that they bounce. How is it done? Your hand inside the glove moves around in a magnetic field in front of the screen. A device the size of a sugar-cube on the wrist of the glove detects changes in the magnetic field as the hand moves through it. The computer reads the changes and transfers the glove's real position at any moment to that of an animated glove on the screen.

future could include both human and computer members.

In the future, musicians and composers will use computers more and more. Already, a lot of pop music is composed and recorded with the help of computers and synthesizers. A computer can store digitally the elaborate pattern of sound waves, say, from a guitar or a drum. Then, on demand, it will send this digital signal to a syn-

thesizer to recreate the original sound. In other cases, the computer and synthesizer can generate totally new sounds never heard before.

In recording studios, computers are being used to 'take apart' the sounds from hit records of the past. A particularly good drum part, for instance, might be 'sampled' from a golden oldie of the 1960s and combined with a recent guitar and voice recording in the hope of making a new hit.

Computers can even write poetry. A collection of words is fed into the computer together with rules for combining those words.

Writing stories

A class at the University of Wisconsin managed to program a computer to create short mystery stories, as an experiment. Each story was about 2,000 words long – and took about half a minute for the computer to write!



Rediffusion Simulation

Just amazing!

FUTURE MASTERPIECE?

COMPUTERS COMPETE WITH HUMAN AUTHORS IN WRITING BOOKS BUT THEIR TITLES ARE LESS THAN INSPIRING, SUCH AS 'THE POLICEMAN'S BEARD IS HALF CONSTRUCTED'.



Paul Raymonde

- 
-  BOMB DETECTORS
 -  ARMoured VEHICLES
 -  BURGLAR ALARMS

Under attack! But an array of technology is now leading the fight against crime.

TECHNOLOGY VS TERROR

IN THE FIGHT AGAINST CRIME today, technology plays an ever-important part. As criminals' methods become increasingly sophisticated, more advanced technology is needed to detect and combat them.

One obvious example is airport security – preventing terrorists from smuggling guns and explosives aboard aircraft. Metal detectors and X-ray machines form the first line of defence. They are used to screen passengers and their hand luggage before they board the plane. Metal detectors are electromagnets that

either take the form of an archway through which the passenger walks, or a hand-held loop passed over the person's body.



X-ray 'eyes'

Any metal objects will alter the magnetic field generated by the electromagnet, and this change in 'field strength' triggers an alarm. Metal detectors can be adjusted to the level of sensitivity required.

X-ray machines are used to examine luggage that is taken on board the aircraft. Bags, cameras, and radios are put on to a conveyor belt which takes them through a

scanning chamber. Because X-rays can travel through most materials, the scanner can form a picture of what is inside a bag or the housing of a piece of electrical equipment.

Identifying the contents relies on how 'transparent' the object is to the X-ray beam. The image is like a photographic negative displayed on a TV screen. A metal object such as a gun would show up clearly.

Similar systems are used to screen luggage before it goes into the aircraft's hold, but X-ray machines and metal detectors cannot trace explosives. Traditionally, searches for explosives have been

Laminated Glass



Just amazing!

SPEEDING BULLET

THE BULLET FROM A 7.62MM FN RIFLE CAN PENETRATE BRICK WALLS AND AT SHORT RANGES STILL COME OUT THE OTHER SIDE WITH ENOUGH ENERGY TO KILL.



Paul Raymond

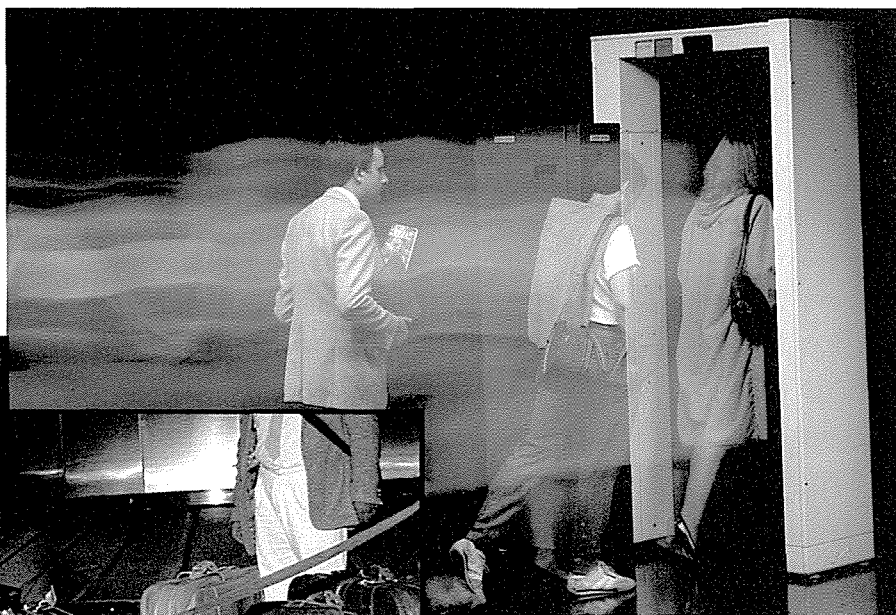
and of what kind.

These electronic 'bomb-sniffers' can be built into a walk-through arch or housed in a hand-held device. Highly sophisticated equipment like this can be very expensive; the TNA explosives detector at New York's John F Kennedy airport has cost around \$750,000!

The threat of terrorist attacks on politicians and other VIPs is another area where technology has its uses.

If, for instance, you see the Prime Minister's car on TV, you might think it looks just like an ordinary car. But this is not so. While the exact details of the way in which it is 'protected' are kept secret, it is thought that the added security equipment brings its total weight to about 230kg more than the standard model.

It probably has 'run-flat' tyres, which allow the car to be driven



Analytical Instruments Ltd



Gamma/Frank Spooner Pictures

even when they are punctured. It is likely to have a much more powerful engine than the standard model, both to cope with the extra weight and to give a good 'get-away' speed if attacked.

Equally likely is the use of armour-plating to protect the engine, the fuel and oil tanks, and the driver or passenger compartments from gun fire and explosions. The thin sheet metal used in ordinary car construction is of little use in stop-

carried out by specially trained 'sniffer' dogs.

But the Semtex explosive now favoured by terrorists has little, if any, detectable smell. To combat this, scientists have developed two different detection systems; one is based on thermal neutron analysis (TNA) and the other uses gas chromatography.

Bomb sniffers

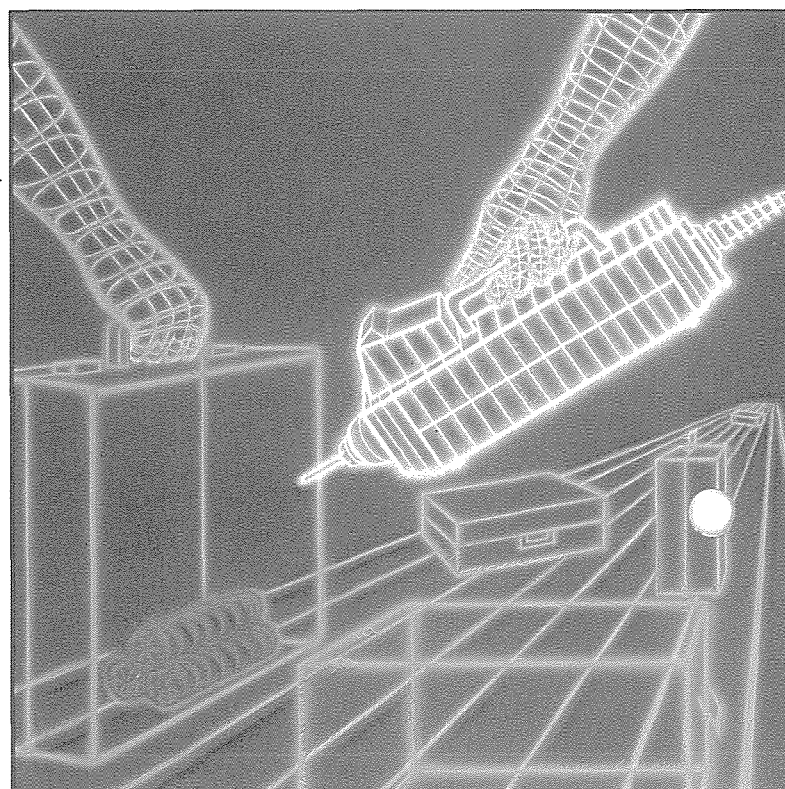
TNA works by bombarding the luggage with a stream of neutrons and analysing the subsequent gamma rays. If the analysis reveals large amounts of nitrogen, it is almost certain to have come from plastic explosive.

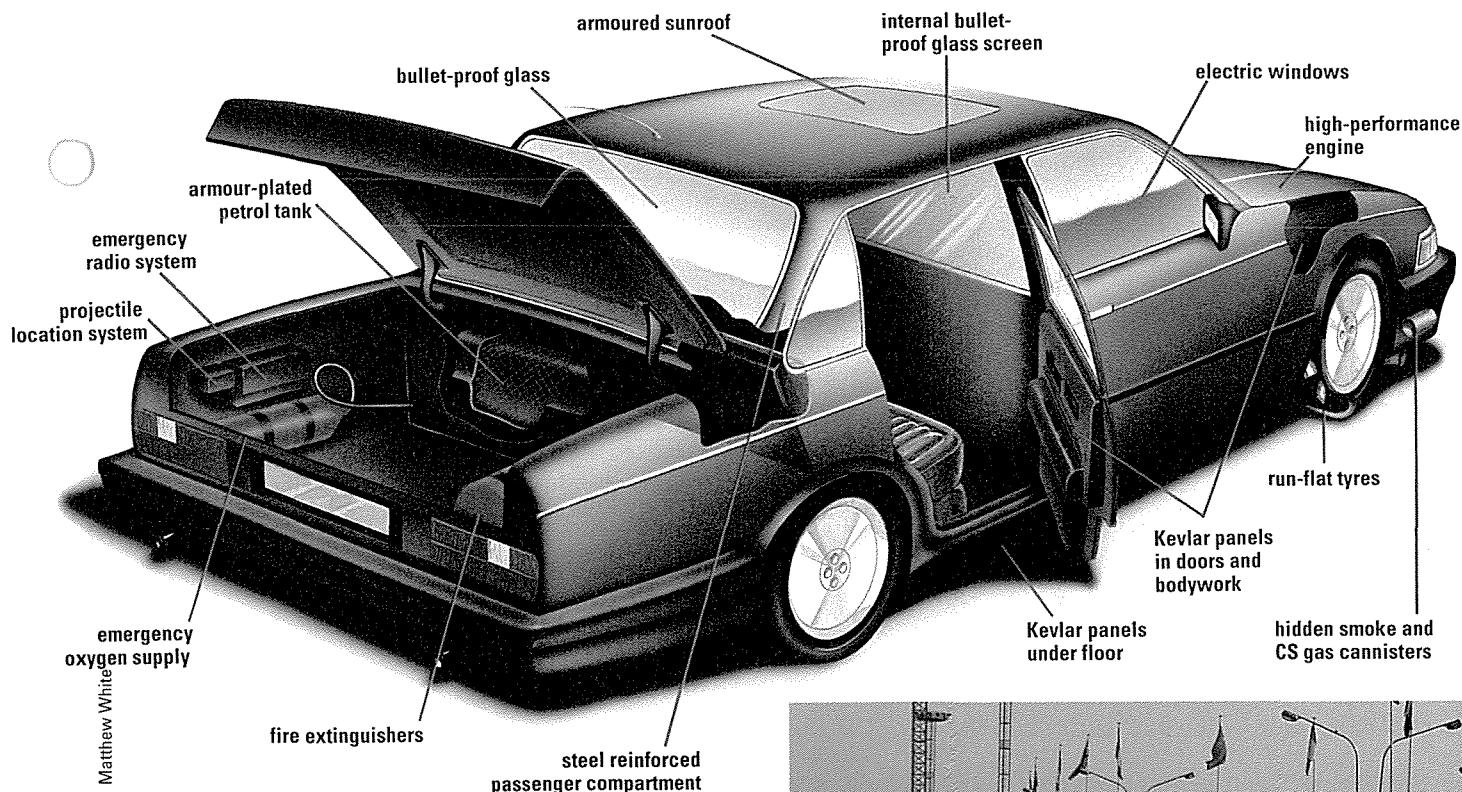
Gas chromatography analyses the air surrounding a suspected bomb. The system uses a sensor filled with a carrier gas, which responds to the unique vapours emitted by, for example, Semtex. Analysis of this gas shows whether there are any explosives present,

'Sniffer' dogs check luggage for explosives, but cannot detect the terrorist's Semtex explosive, which has no smell. Now aircraft passengers pass through a 'sniffing doorway', which analyses the chemicals in the air around them.

Analytical Instruments Ltd

This bomb detector is portable and fits into an attaché case. It can check cars, parcels, luggage and rooms, and will quickly detect the vapours given off by explosives.





ping the fire from high velocity weapons such as rifles.

While armour-plating will do the job, conventional materials like steel are too heavy to be used on VIP cars. The answer comes in the form of lightweight materials such as Kevlar plastic, which is capable of stopping bullets up to a calibre of 12.7mm.

VIP vehicles

In the case of such a car, sheets of Kevlar, or a similar substance, are likely to be installed in the door panels and in the bulkheads in front of and behind the passenger compartment. It may also be used under the car, to protect against bombs placed underneath. The passenger compartment will be strengthened to protect the car should it be blown over on to its roof.

Kevlar works like bullet-proof

VIP vehicles may look ordinary, but they conceal a host of extra features.

Armour-plating, bullet-proof glass and a strengthened passenger compartment help protect against gunfire and bombs.

Rex Features Ltd



glass — another feature of VIP vehicles — in that it absorbs the energy of the bullet, slowing it down sufficiently to prevent it penetrating the armour. Bullet-proof glass achieves this effect by being made up of layers, or 'laminates', that are arranged so that they will slow down a bullet and at the same time prevent the glass from shattering.

The same process is used in bullet-proof vests, which can resist shots from rifles, pistols and shotguns. A basic bullet-proof vest comprises protection for the front and back of the wearer's body from waist to neck. The armour is made of materials such as Kevlar, which is padded to make it more comfortable. A bullet-proof vest does not prevent all injuries; the wearer may suffer broken ribs or severe bruising, but will not be killed.

Protecting property

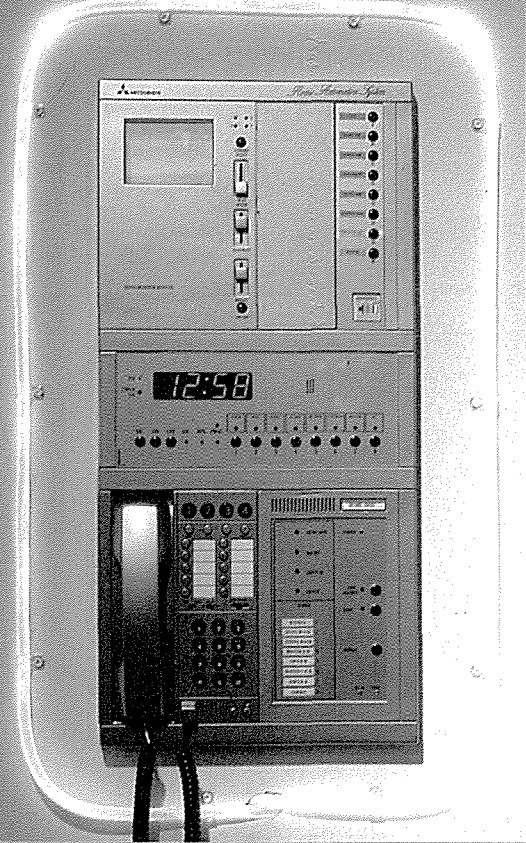
So much for life-saving technology. Just as important is security against theft and espionage. In the UK, for example, there are over one million burglaries per year, which means a burglary takes place every 30 seconds on average.

Burglar alarm systems can be simple or complex. A simple system will be linked to the doors and windows of a building, and will trigger an alarm when there is an unauthorised entry. In such a system, a wire and magnet circuit connects all doors and windows

Full security alert

at Vienna airport. This police tank will be called into action in the case of a hijacked plane or a terrorist attack inside the airport. The policeman is wearing full body armour, and has a high-velocity rifle trained on the target plane. Police and armed forces carry out regular defence exercises to prepare for the real thing.





Jerrican/SPL

Security systems for the home are able to monitor every room for intruders or fire, using video cameras, sensors and a centralized computer.

frame, which is wired into the system. To beat this, alarm designers have come up with new ideas such as pressure plates and sensor beams.

Pressure plates react when, for example, someone treads on them. They can be fitted under carpets or to windows, so that they go off if someone pushes against the glass.

Electronic eyes

Infrared beams are invisible to the human eye and can be transmitted across the access points of a building. If an intruder crosses the beam, the circuit is broken and the alarm goes off. In some systems, spotlights also come on as soon as the beam is broken.

Similarly, ultrasonic and microwave detectors send out beams that trigger alarms if they are broken by someone passing them.

The passive infrared detector picks up the infrared energy radiated by all objects. Human movement will cause a sudden change in the energy levels, which will trigger an alarm.

Other new types of 'key' include card entry systems, which resemble credit cards with an electronic code built into them, and digital locks, where a correct number has to be tapped out to gain access. Even more sophisticated entry systems identify individuals by their fingerprints or the unique blood vessel pattern of the eye, and then comparing them to the patterns of authorised users.

A common security device to keep out unwanted callers is an entryphone system, which allows householders to speak to visitors on a type of phone before opening the door. Some homes are fitted with a videophone system, which uses closed-circuit cameras connected

to the TV set or a mini-screen.

Even more secure than houses and offices are, by necessity, bank vaults. To protect against robbers with high power drills, oxy-acetylene torches or perhaps even explosives, the walls of a strong-room are made from steel-reinforced concrete blocks, with detector strips built in to warn of intruders burrowing through. The steel doors are up to one metre thick, with a dozen or more bolts.

They have combination locks, with up to 100,000,000 different



Safe inside a can. These worthless looking cans are in fact cleverly disguised safes. No burglar would think of looking inside them for valuables.

Diversion Safes (C-R) Ltd

combinations of numbers, thus reducing the chance of a criminal 'guessing' correctly. They may also use time locks.

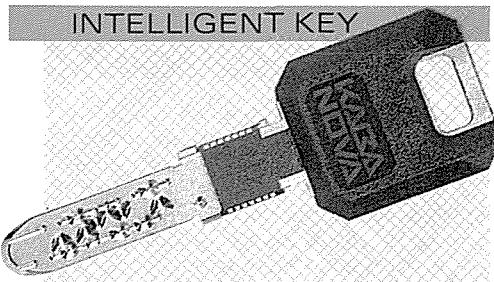
Very few systems would claim to be foolproof; given sufficient time and equipment, determined bank robbers can break into the strongest of strongrooms. But security measures like these at least make life much harder for the criminal, and thus greatly aid the world's police forces.



ZEFA

Bank vaults have doors up to one metre thick, tapered to give an airtight seal and protected by a dozen or more bolts. Combination and time locks help make them virtually thief-proof.

INTELLIGENT KEY



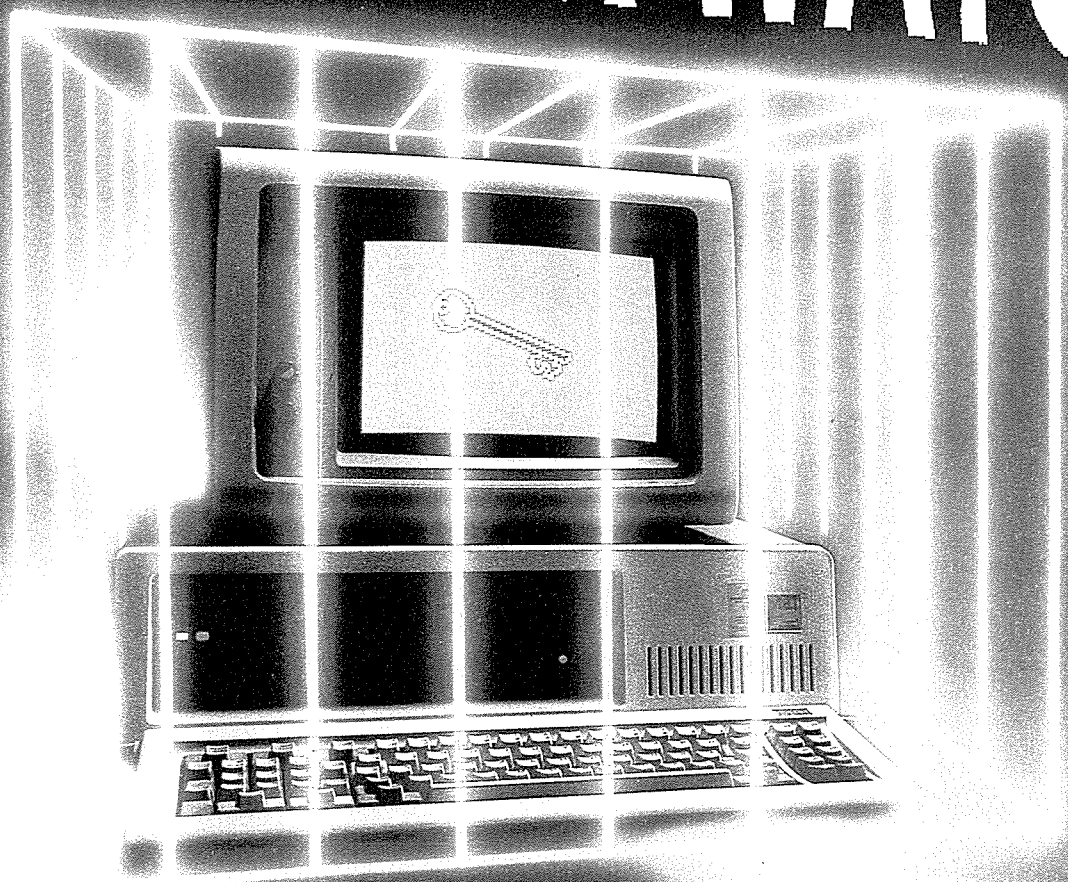
Kaba Locks Ltd

A Swiss company has developed an ingenious key with its own computer circuitry. This 'intelligent' key has a number of unique functions, thanks to its own integrated circuit board in the mid-section.

It can be programmed by a central command centre, which also programmes the locks in doors, windows and cupboards. The special locks decode the information contained in the key, giving total control over access to each lock. The key can even record the previous 128 movements, itemized with date and time of access.



COMPUTER WATCH



Telegraph Colour Library

- Q FRAUD AND THEFT
- Q SCRAMBLING SIGNALS
- Q PASSWORDS

COMPUTER TECHNOLOGY influences our lives in every way. For example, our medical records and information about motorists and their cars are stored in central computers; and most shops now accept payment by cards, which a computer reads to transfer payment.

The world's economy is run by computers in the sense that most buying and selling operations are computerized. So, if a Swedish company buys goods from a British one, a bank in Sweden will pay the British company automatically by computer.

There is also widespread computerization in the world of stocks and shares. Almost all share dealings are done by computer. In larger organizations, a computer automatically informs the operator whether a particular share should be sold. This dependence on computers makes it important that such systems are well protected from unauthorized users inside or outside the company.

Hi-tech thief

As the use of computers has become ever more widespread in everyday life, the rate of computer crime has risen alarmingly. The most common form is fraud whereby, for example, a bank employee uses his or her knowledge of the system to steal money. In one method, the thief transfers small amounts of money from a large number of accounts into one of his or her own.

Locking up the data of a computer system is not enough to keep it secure from spies and hackers, who break in for fun or to insert viruses.

The trick is to transfer only amounts that are too small to be readily noticeable. The thief's task is made much easier by the fact that most people do not check their bank statements, so a couple of pounds missing goes unnoticed. Also, banks deduct fees for services automatically, so the disappearance of small sums from a particular account is difficult to spot.

Eavesdropping

Another type of computer crime is the theft of information from data banks. One method is to bribe an operator to supply data from within the system. Much less risky is 'external bugging' - tapping into the





almost any computer system.

The first objective is to find the target's phone number. Having got into the system, the hacker then has to breach security. To give users access, many databanks have simple passwords. Finding the password may require a lot of research.

The hacker might insert into the network a 'Trojan Horse' program which gives easy re-entry without the system's operators knowing

system from outside.

The monitor or Visual Display Unit (VDU) of a computer transmits a radio signal while it is switched on. This radio output varies in exactly the same way as the electronic signal for building up the screen image, so it is possible to reconstruct the image from the radio output, using a TV-type receiver.

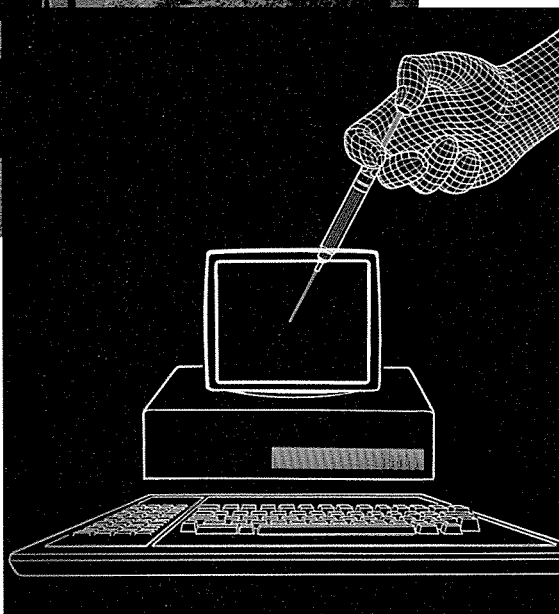


Revealed

The ease with which information can be extracted was shown in 1986, when a journalist from the British newspaper *The Guardian* took part in an experiment in which such equipment was driven in a car around the town of Cheltenham. The team displayed information from banks and solicitors' offices.

This kind of bugging can be beaten by the use of 'Tempest' techniques, which cover all aspects of computer security. Tempest techniques are secret, but they are thought to include screening the VDU with materials that absorb radio waves and using small trans-

Tony Craddock/SPL



A rogue program, inserted into a computer system, has a similar effect to a virus in the body – it stops functioning properly. Ian Murphy, alias Captain Zap (inset left), did not intend to harm the systems he hacked into, but he was found out and convicted for computer piracy.

Network users, such as banks and insurance companies, use passwords or codes to give employees access to certain levels of the system. Sometimes there is a separate network linked to the system and manned by security staff for the sole purpose of preventing fraud.



ZEFA

Just amazing!

COMPUTER SICKNESS

IN NOVEMBER 1988, A 'COMPUTER VIRUS' INTRODUCED INTO THE US MILITARY'S ADVANCED RESEARCH PROJECTS AGENCY NETWORK (ARPANET) KNOCKED OUT NO FEWER THAN 50,000 COMPUTERS THROUGHOUT THE USA IN ONE DAY.



Paul Raymond

mitters to 'scramble' the signal from the electron tube.

Tempest techniques are also used to defeat hackers – people who use their computer illegally to tap into other computer systems. Hacking began in the 1970s as a game in which people pitted their intelligence against that of the designers of security systems for computers.



On target

Equipped with a micro and a modem (from MODulator-DEMODulators – devices by which computers receive and transmit data by telephone), hackers can break into

security has been breached.

Hacking ceases to be a game when it is used for espionage purposes or to introduce a 'computer virus' into a system. A computer virus is a rogue program inserted into the system to destroy it.

Once a virus has been discovered, there is no option but to shut down the system and eradicate it from the programs that guide the computer through its tasks. A virus introduced into a banking system can cause great disruption and massive expense. The same sort of program put into a hospital computer system by a malicious hacker might harm or even kill people.

SUBWAY SYSTEMS

TUNNEL DIGGING

'EARTHSCRAPERS'

MILLIONS OF PEOPLE POUR into the world's major cities everyday on underground railway systems. Crowded, noisy and expensive to build, they are still providing the best means of public transport.

As early as the mid-19th century, city streets were so congested that plans were made to build underground railways. The first one to open was the Metropolitan Line between Farringdon Road and Paddington, London, in 1863.

The first subway in America was in Boston, followed shortly by the New York subway, the longest system in the USA with 373 km of track. The tunnel is rectangular in cross section, with steel roof beams and columns beneath concrete arches.



Smoked out

All these early underground trains were pulled by steam engines, which were equipped with condensers that turned the steam back into water for reuse. But nothing could be done about the smoke which filled the tunnels.

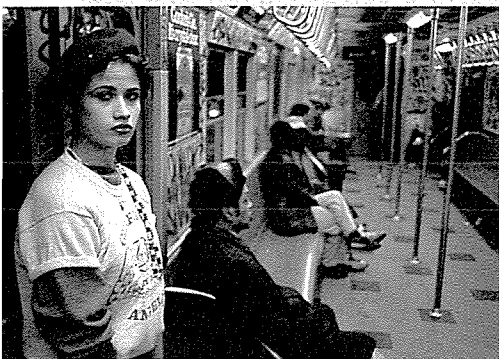
The New York subway has a remarkable safety record, thanks to

RATP, Paris

The Paris Métro is considered one of the most sophisticated underground railway systems in the world. It is controlled by a centralized computer system which monitors the stations.



GUARDIAN ANGELS



Rex Features

The Guardian Angels were set up as a voluntary crime-fighting force on the New York subway in 1979 by Curtis Sliwa and his fashion-model wife Lisa. Their intention was not to act as a vigilante group, but as deterrents to would-be violent criminals, first on the subway and then in the city at large.

Their membership soon expanded to 5,000 across 60 US cities, and they have set up 'chapters' in Canada, Mexico and London. The Guardian Angels have constantly been criticized by conventional police forces, but they have helped reduce crime levels.

The world's longest tunnel links the Japanese islands of Honshu and Hokkaido. Of its 53 km, only 23 km lie under the sea – whereas the Channel tunnel has 38 km out of 50 km underwater.



Rex Features

its high level of automation. An elaborate signalling system divides the track into blocks, which are controlled by whichever train is in that block, thus preventing any other train from entering it.

On many lines the subway has the advantage of two tracks running in each direction so that express trains, only calling at selected stations, can run at the same time as the 'locals' which stop at all stations. This also make it possible for trains to run all night on one track while maintenance work is done on the other – most systems have to shut down at night.

Graffiti and violence make the New York subway an unpleasant and dangerous ride. But more than 5 million use it each day.

SUBWAY VIGILANTE

In 1984, Bernhard Goetz shot and wounded four would-be muggers carrying sharpened screwdrivers on a New York subway train. After a celebrated court case, Goetz was acquitted of attempted murder and assault, but finally sentenced to a year's prison for carrying an unlicensed gun.

Honshu side

Hokkaido side

Tsugaru Straits

inclined shaft
(for maintenance
workers and materials)

vertical
shaft

maintenance car

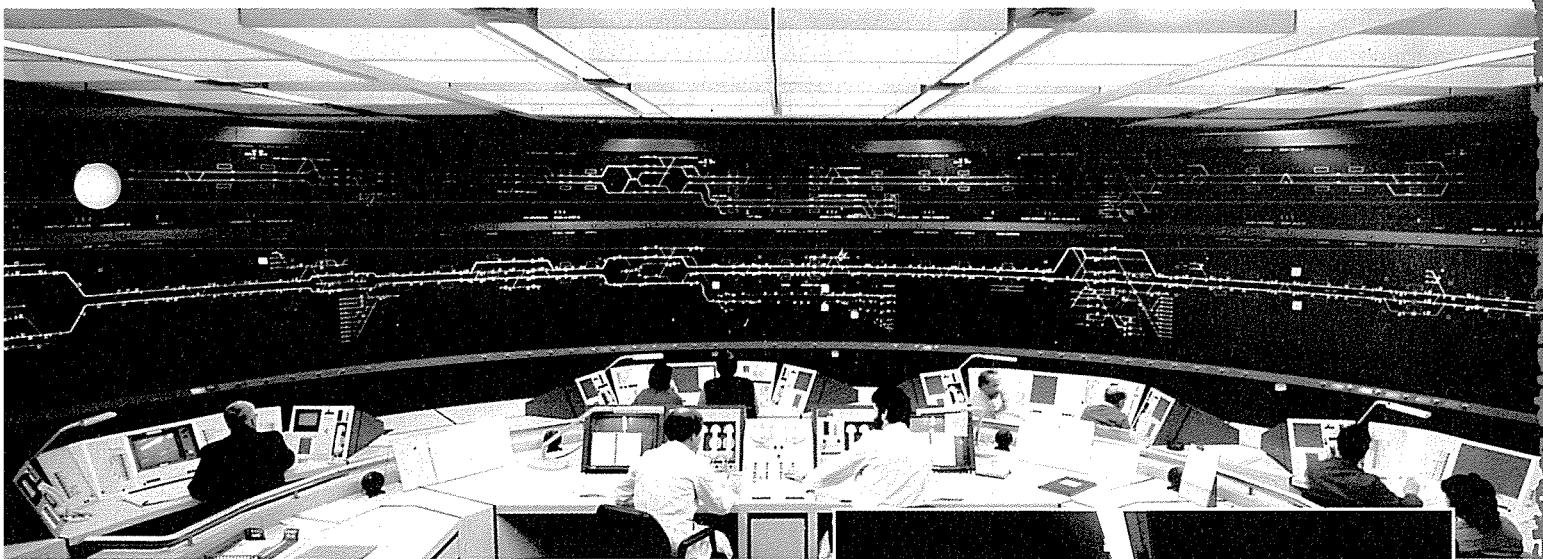
service tunnel (for maintenance and ventilation)

conventional train

main tunnel

pilot tunnel (for drainage and ventilation)





More than five million passengers use the system daily, although it has a reputation for crime and violence.

Other subway systems run in Boston, Chicago, Washington DC and Philadelphia. The Bay Area Rapid Transport system, which serves the San Francisco region, runs for 6 km underwater along the Bay. It is very advanced technologically, with fast, light-weight carriages, automatic train control and automatic ticket collection. There are no staff, and computers in Oakland monitor the system so that carriages can be added when appropriate to ensure every commuter has a seat.

Futuristic trains and computerized control centres are part of the newly-modernized Paris Métro. The MF77 train has been designed to maximize space and comfort. A computer system cuts in and alerts the control centre if the driver is suddenly taken ill.



RATP, Paris

TOKYO MADNESS



Jean Paul Nacivet/Colorific

One of the busiest subway systems in the world is the Tokyo metro, which provides around two billion passenger rides a year on its relatively short track length. 'Pushers' have been used to pack more than 300 people into each car during the rush hours.

Like the Tokyo metro, other subways in Japan are heavily commercialized with numerous restaurants and stores. The Japanese government is currently investigating the possibility of building ultra-deep new lines more than 50 metres underground to avoid the cost of purchasing enormously expensive surface land.

The London Underground, with 408 km of track, is slightly longer overall than the New York subway, making it the most extensive system in the world. The distance covered by all London tube trains in a year is 49.2 million km which is the same as travelling to the Moon and back 64 times.

More than two and a half million passengers travel daily on the system, which is connected to mainline railway stations as well as the Docklands light railway. The great depth of the stations made them invaluable as air-raid shelters for Londoners during World War II, protecting 60,000 people each night.

The tube trains are slightly smaller than British Rail surface trains, and are designed to run through 3.85-metre wide tunnels at an average speed of 33 km/h. Other British cities with subway systems include Glasgow and Newcastle.

Paris Métro

The Paris Métropolitain (Métro) subway system is run by a state-controlled body which has instigated superb modernizations and extensions since the early 1970s. The result is that the Métro is now regarded as one of the finest transport systems of any world city, carrying an estimated five million passengers daily. There are 16 main lines which provide a comprehensive cover of the city, many of the stations being a short walk from each other.

The Métro is connected to the Réseau Express Régional (RER) high-speed express subway system which extends far into the suburbs and at some points has been integrated with the mainline railway network. The hub of the system is Châtelet-Les-Halles which is the world's largest and busiest underground station. The system has some unusual features compared to other subway systems, with two classes of service, special seats for the handicapped, electronic route-planners, and rubber-tired cars.



Paul Raymond



EUROTUNNEL

The most important form of transportation in Moscow is the Metropolitan subway. The stations are noted for their elaborate architecture and decoration with marble pillars, chandeliers and stained glass. The network is designed along a series of radial lines linked to a single ring subway. Heavily subsidized by the government, the system is the world's busiest with nine million passengers a day. Other Russian subway systems exist in St Petersburg, Kiev, Tbilisi, Baku and Kharkov.

In Canada, the Toronto subway uses steel-wheeled cars, steel rails and shallow trenches. In contrast, the Montreal subway uses light-weight, rubber-tyred trains which run through rock tunnels deep beneath the city streets.

Other major systems more than 40 kilometres long include Berlin and Hamburg, with smaller systems running in Athens, Barcelona, Budapest, Buenos Aires, Copenhagen, Mexico City, Milan, Madrid, Rome, Stockholm, Sydney and Vienna.

Electric-powered

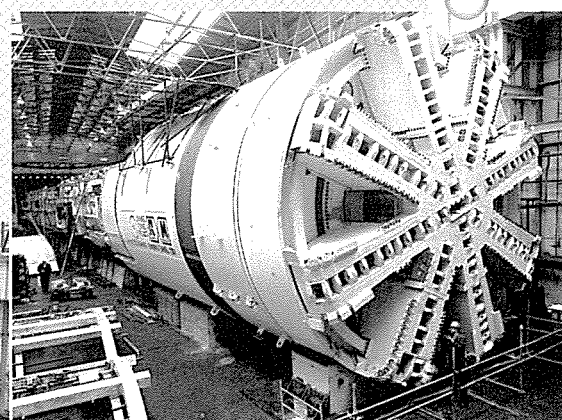
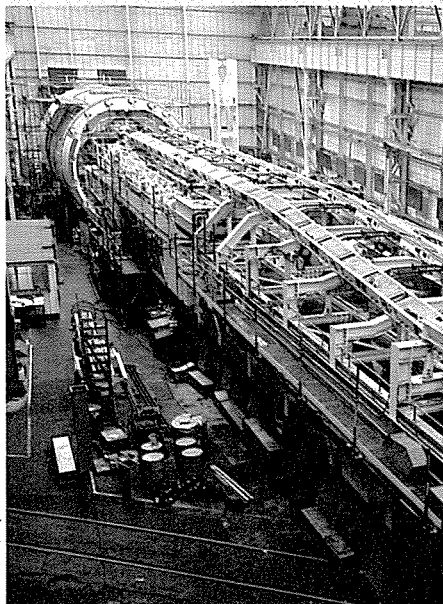
Most of the world's underground railways are powered by direct current delivered to electric motors through a third – and sometimes even a fourth – rail alongside the track. At stations the power rail is always on the side away from the platform. On some railways the locomotives pick up the current from the underside of the rail, which is topped by a safety cover.

The earliest tube tunnels were built by the 'cut and cover' method, where a deep trench was dug and

The Channel Tunnel provides an underground rail link between Britain and France from late 1994. The twin-rail tunnel travels for 38 km under the sea, 70 metres below the sea bed, making it the world's longest undersea tunnel. It was dug through a layer of 'soft' chalk, using giant tunnel boring machines – TBMs. The TBMs had 4.8 metre cutting heads, were up to 270 metres long and bored through the rock at 1 km per month.

The French TBMs worked from the

other side of the Channel and the tunnel should be fully operational by the summer of 1994. It will halve the journey time between Paris and London to three hours.



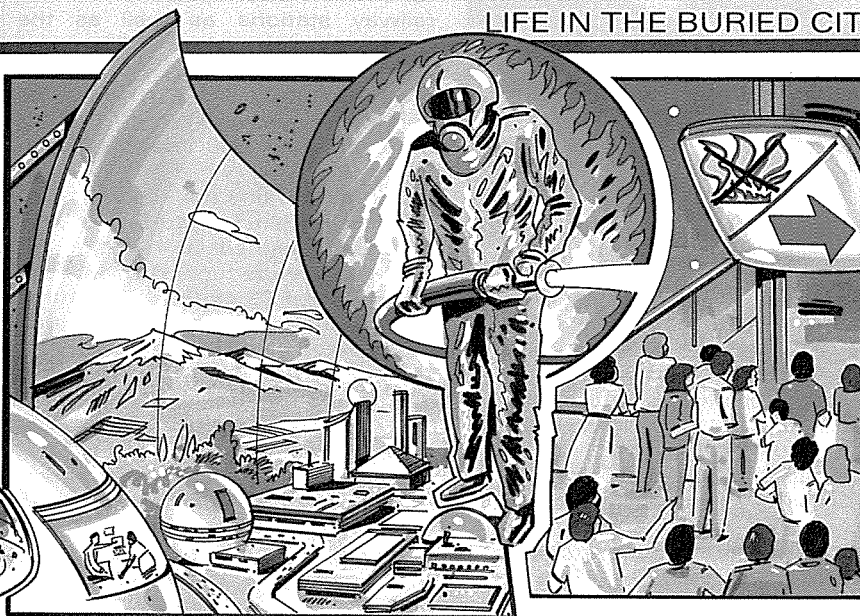
QA Photos, Hythe, UK

lined with brick or concrete. Then it was covered over with brick arches or girders to form a roof, and the excavated soil was replaced over it. 'Cut and cover' is the ideal method for tunnels near the sur-

face. But tunnel-boring through the ground is used deeper down. In the old days, the tunnels were dug by gangs of labourers using pick-axes. Now Tunnel Boring Machines – TBMs – use rotating cutting teeth.



▲ Eventually the pressure to accommodate expanding populations will lead to the construction of underground cities linked by trains.



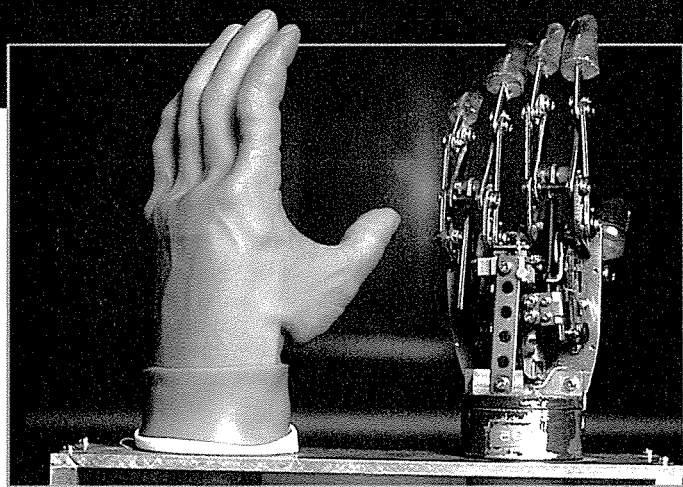
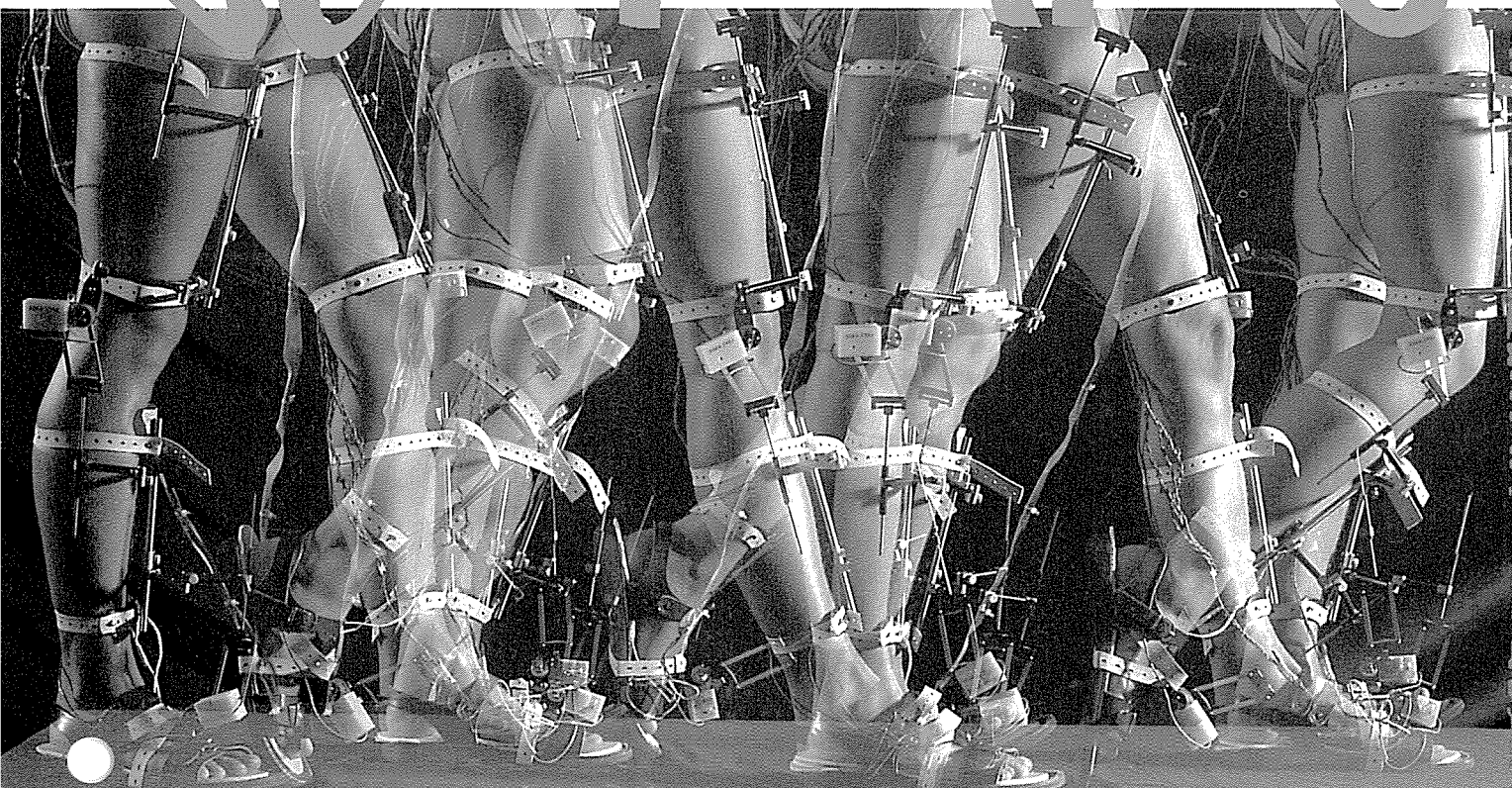
▲ Vast high-definition TV screens would provide scenes from the planet surface, to keep the underground inhabitants in touch with the outside world.

▲ Because of the large fire risk, there would have to be safety zones with supplies of air and power which could be sealed off in an emergency.

Jane Lawrence



BODY PARTS



Claude Charlier/Science Photo Library

THE HUMAN BODY IS A remarkable machine, but one vulnerable to disease and damage. Yet just like a machine, when some body parts fail because of illness, injury or wear and tear, their functions can be taken over by artificial replacements.

For example, modern science has provided electronically controlled artificial arms for people who have suffered an amputation above the

elbow. Tiny skin electrodes are attached to muscles in the upper arm or shoulder, which can be used to trigger the arm to move up or down. Signals can also be sent to vary the firmness of grip of an artificial hand, so that it can pick up an egg or crush a soft drink can. Scientists are currently developing even more sophisticated artificial hands with touch sensors in the fingers.

Some cases of deafness have

Artificial limbs can now mimic the movements of real arms and legs with the help of computer-aided designs. Electrodes detect electronic impulses from the upper limb muscles, and can re-create these signals in motors in the false parts (left).

been overcome by the use of a bionic ear. Electrodes implanted in the inner ear send messages to the brain. While ear implants have given deaf people some sensation of sound, there is still some way to go before they will be able to hear the full range of sounds.

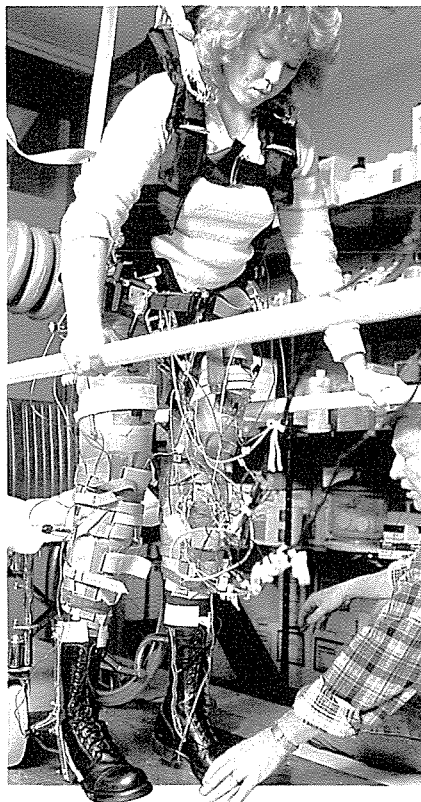
Learning to walk

People with spinal injuries who have lost the use of their legs are being helped to stand and walk again, thanks to new types of electrical stimulation. By stimulating muscles in the legs via electrodes, and providing braces to support the knee joint, paraplegics have been able to perform rudimentary walking.

Bioengineers have also developed a highly durable artificial elbow, a very complex joint, which is made of polyethylene and a cobalt-chromed alloy. This joint is particularly useful for people whose joints have been destroyed by arthritis. There are also similar artificial joints

ZEFA





Learning to walk with mechanized legs is a long and complicated business.

An artificial hip joint, as seen by X-ray. The metal head fits into a plastic socket.

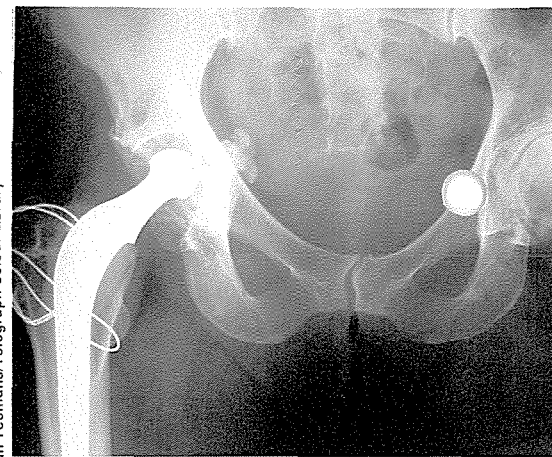
whose ball fits into the hip socket, is removed and is replaced by a metal head. This is attached to a long stem, which is cemented into a hole drilled into the rest of the thigh bone.

By analysing the stress forces on the hip, engineers can now produce artificial hip joints good enough to withstand the forces of the human body for more than 25 years.

Longer legs

In some tragic cases, young children have had their legs amputated because of bone tumours in the long bones. However, scientists have developed artificial bones made of tungsten carbide and incorporating a knee joint which can be attached to the remaining leg

bones. What makes this implant so special is that it can be extended at various intervals by injecting ball bearings to force out a piston. This overcomes the problems of leg length previously associated with growing children. Eventually it is hoped that the artificial limb will

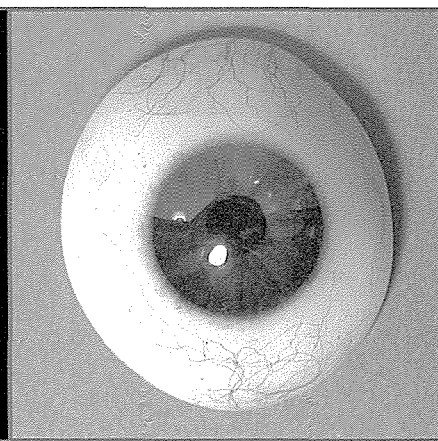
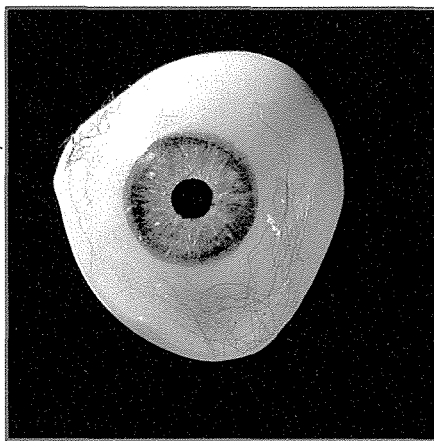


Ian Yeomans/Telegraph Colour Library

for knees, shoulders, fingers and ankles.

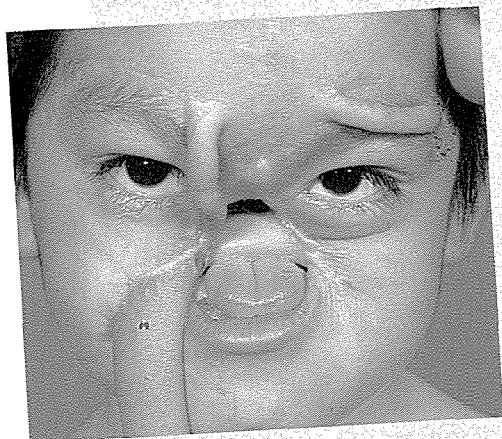
Millions of people suffer hip joint damage as the result of arthritis, which can mean a loss of mobility as well as excruciating pain. An artificial hip joint has proved the answer. The last 30 years have seen great improvements in the quality of artificial hip joints made from metal and plastic. The operation involves gouging out the socket of the joint, and replacing it with a sturdy plastic cup. Meanwhile, the head of the femur, the long bone in the leg

James Stevenson/Science Photo Library

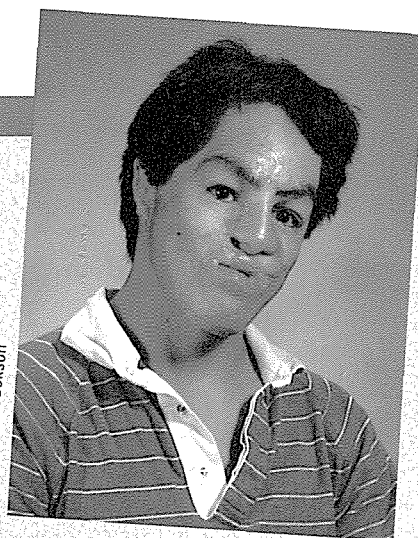


A NEW FACE

David is a young Peruvian Indian boy who had not developed an upper jaw or nose because of malnutrition or infection. Scottish plastic surgeon Ian Jackson and his wife Marjorie met David in Lima. They were later persuaded to begin rebuilding his face when they were back in Glasgow.



Ian & Marjorie Jackson



Tubes of flesh – known as pedicles – were grafted from David's body on to his face. As they 'took root', they were moulded into an upper jaw and nose, involving nearly 100 operations over ten years. The emotional trauma was probably as severe as the physical pain – but now David has a whole face.

Glass eyes come in all colours, but cannot 'see'. Tiny TV cameras may be used in the future.

contain a motor so that extension can be achieved by remote control.

In cases of face cancer, large pieces of bone and tissue may need to be removed. Now an artificial 'skin' can be moulded to match the remaining parts of the face, and coloured to match the skin shades. Tiny terylene fibres can even be inserted to mimic the small blood vessels under the skin. Tubes – or pedicles – of flesh can also be used to transfer 'healthy' skin from one part of the body to another in cases of facial deformity or illness.

Electronic eyes

Blindness is another disability which is being studied. Scientists have already managed to electronically stimulate visual centres of the brain to enable blind patients to 'see' silhouettes and moving objects. By the end of the century they may be able to implant TV cameras the size of hazelnuts into eye sockets to enable blind people to see.

HOME FROM HOME

FOR MANY PEOPLE, HOME may only be a temporary resting place. Soldiers, sailors and oil rig workers may spend months, even years, away from home. They need to make the most of their living quarters – so that they have a home from home.

For most workers on a North Sea oil production platform, life is split into two distinct halves. Two weeks on the rig, working 12 hours or more each day is followed in most cases by two weeks off. The offshore installation manager who is in charge of the rig may be on call 24 hours a day. Saturation divers do a longer stretch of four weeks on and four weeks off and, when working,

live in special decompression chambers, which match the high pressures they are under when diving deep down. The pressure 150 metres underwater is 15 times normal pressure, so a pressurised gas (helium/oxygen) is used to match this atmosphere in the chambers while they are living in them.



The 'bends'

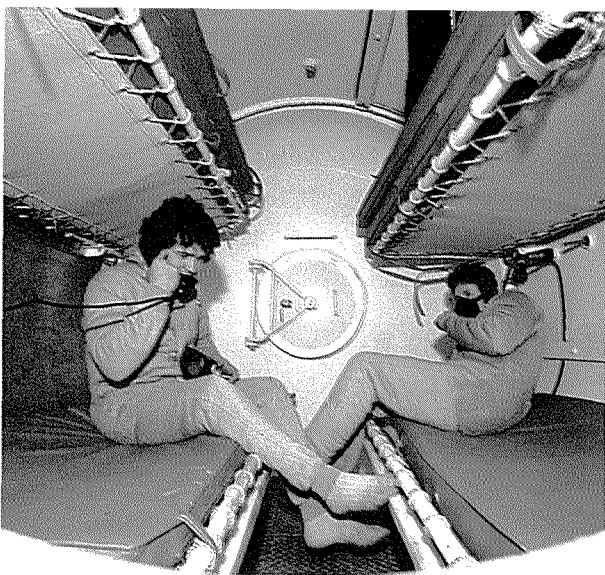
This means that the divers only have to undergo the slow process of decompression once a month, at the end of their stint. Otherwise they would have to be decompressed after each deep dive, to prevent them suffering from the 'bends'. This is a condition caused by nitrogen bubbles appearing in the blood when a diver returns to

Oil rig workers use huge amounts of energy and need to be well-fed. Their canteen facilities are first-class, offering a wide variety of food, flown in by helicopters.



Shell UK Ltd
Exxon Corporation

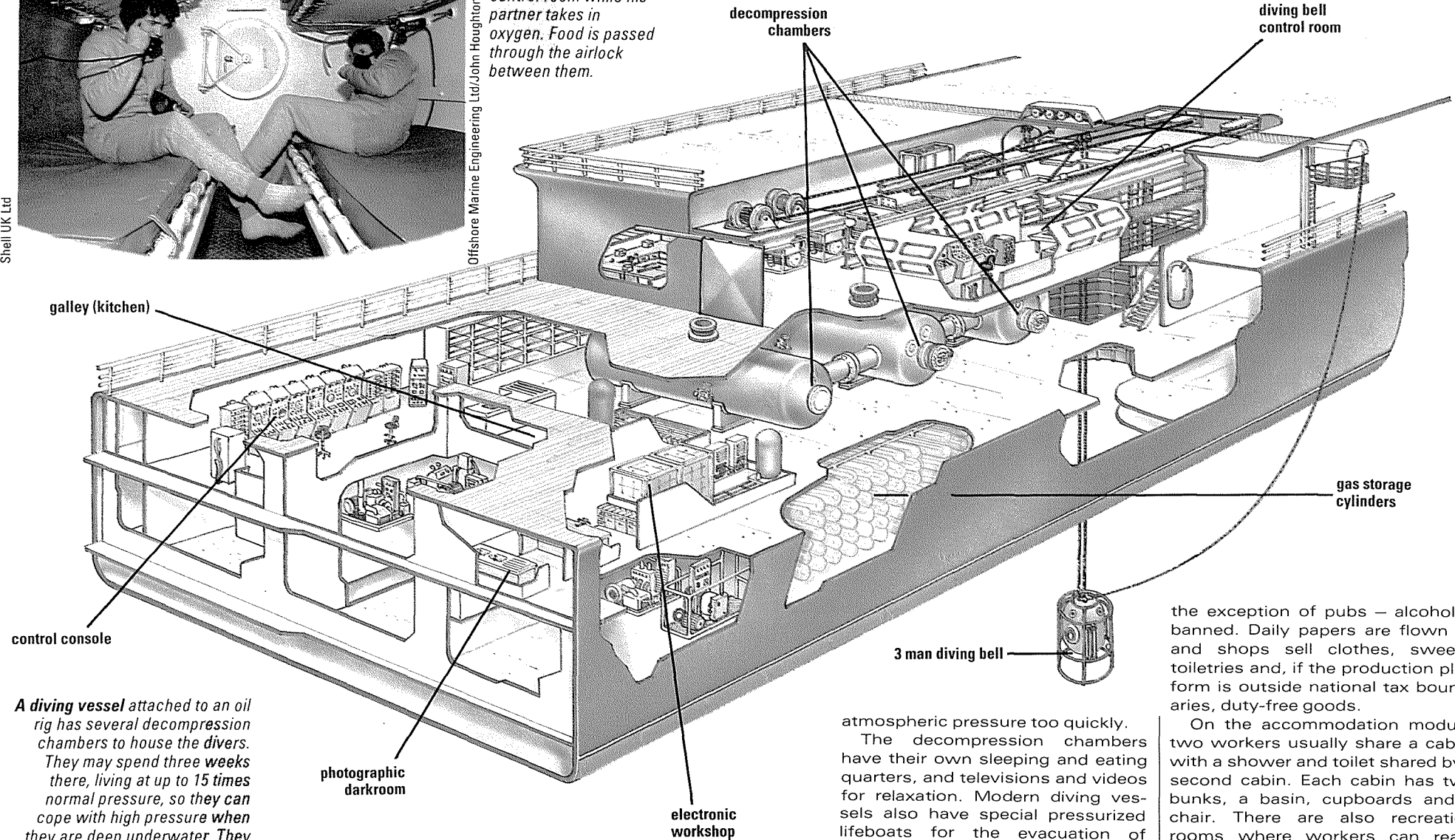




A decompression chamber. The diver on the left is talking to the control room while his partner takes in oxygen. Food is passed through the airlock between them.

Offshore Marine Engineering Ltd/John Houghton

Saturation Diving Vessel



A diving vessel attached to an oil rig has several decompression chambers to house the divers. They may spend three weeks there, living at up to 15 times normal pressure, so they can cope with high pressure when they are deep underwater. They only need to undergo decompression once a month, instead of after every dive.

atmospheric pressure too quickly.

The decompression chambers have their own sleeping and eating quarters, and televisions and videos for relaxation. Modern diving vessels also have special pressurized lifeboats for the evacuation of divers under pressure in an emergency.

Oil rigs manage to carry most of the facilities of everyday life, with

the exception of pubs — alcohol is banned. Daily papers are flown in, and shops sell clothes, sweets, toiletries and, if the production platform is outside national tax boundaries, duty-free goods.

On the accommodation module, two workers usually share a cabin, with a shower and toilet shared by a second cabin. Each cabin has two bunks, a basin, cupboards and a chair. There are also recreation rooms where workers can read, write, watch TV or play snooker. There is a choice of films each day in the cinema and there is a library. Computer and photographic clubs



Rex Features

are popular, and many platforms arrange charity bingo or quiz nights.

Exercising facilities are available, with weightlifting equipment, running machines and exercise bicycles. The canteen food has a high reputation and there is a wide range of choice. Drinking water is brought in with regular supplies.



Floating cities

The largest US aircraft carriers have a crew of over 7,000 men. A sailor mess deck will house 20–30 bunks, while junior officers will probably share with three others. A more senior officer will have his own cabin, which doubles as his office, and the highest officers have separate day and night cabins.

Most washing and lavatory facilities are shared. Fresh water is carried in tanks, but a condenser system turns sea water into fresh water – on newer ships a chemical exchanger separates the salt from sea water.

Satellite dishes can receive and transmit television programmes, and films are shown two or three times a week. There may be 250 men working in the canteens and galleys, preparing a wide range of food. Civilian teachers help sailors continue their high-school or col-

'Floating cities'

Weighing up to 90,000 tonnes and carrying as many as 7,000 crewmen, aircraft carriers can be as long as three football pitches.

Submarine life, by

contrast, is very cramped. Each crew member has only around 2 square metres of space to himself.

US Navy/Department of Defense



while others work.

The ship has to be self-sufficient for months on end, and good food is important in these confined circumstances. Huge refrigerated stores hold enough food, together with tins and dried foodstuffs, for around four months. Bread is made daily. The air is recycled using a system that removes the CO₂ from the air. But it does not remove smells, so the aroma of food can stay for days.

One of the main problems of

DOWN A FOXHOLE

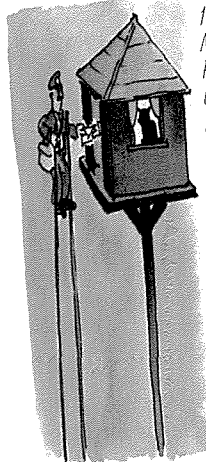
For members of the British Special Air Service (SAS), a temporary home may be nothing much more than a hole in the ground. When acting invisible, it is important to leave no traces, so excrement is always buried. Smells associated with man, such as deodorant and soap, are too revealing – an unwashed human is much more likely to remain unnoticed.

Army rations include water purification tablets, waterproof matches and highly nutritious tinned foods that can be eaten both cooked and uncooked. The SAS also learn to trap game and fish and to identify edible fungi, seaweed and other plants. Survival training also includes evading dogs by wading through water or hiding among farmyard animals whose scent covers their own. In the army they say you can recognize an SAS man by the way he walks backwards through the snow!

ZEFA

Just amazing!

HIGH-LIVING



19-YEAR-OLD MELLISSA SANDERS FROM INDIANA, USA, SPENT 18 MONTHS, FROM 1986–1988, LIVING WITH HER CAT IN A 2 X 2.5 METRE HUT ON TOP OF A 13 METRE POLE. HER MOTHER HAD SET A PREVIOUS RECORD OF 211 DAYS (7 MONTHS) IN 1959.

Paul Raymonde

lege education, and a chapel serves all religious denominations.

Aircraft carriers have far more space than other ships, which means they are ideal for concerts or parties. Entertainers can be specially flown in. Traditional team games can also be played, as long as they are adapted to suit the surroundings, and there are aerobics and fitness sessions.



Life underwater

The crew of a nuclear submarine may spend months away from home. There may be weeks without daylight, no change between night





CopyWriters

living like sardines — space works out as 2 square metres per man — is the lack of chances for normal exercise. So there are exercise bikes and weights available.

Raw sewage is held in tanks and reduced biologically before being pumped out. This has to be done carefully to avoid giving away the submarine's whereabouts. The sonar equipment is so sensitive that it can detect a ship above by a door shutting. Operators even get to recognize individual ships by the noises they make!

Living on the wing

Dick Rutan and Jeana Yeagar spent 216 hours in the cigar-shaped cockpit of the aircraft Voyager in December 1986. The 40,000 km trip was

No room to spare.

Dick Rutan looks out of the cockpit of the record-breaking aircraft Voyager, which flew round the world non-stop in 9 days. His co-pilot Jeana Yeagar shared flying duties in the tiny cabin.

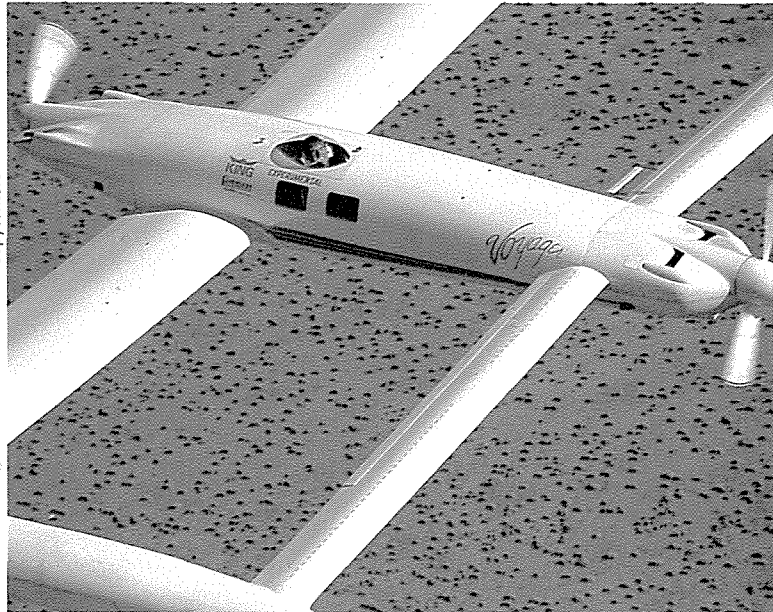
the first round-the-world non-stop unrefuelled flight.

Flying duties were shared in the tiny cabin, which was enclosed by a close fitting bubble canopy. The non-flying crew member slept in a bed behind the pilot and changing places involved one climbing over the other — a dangerous procedure

taking about a minute while the plane was on autopilot.

They wore special pyjama-like flying suits designed to maintain body temperature and absorb sweat. Sponge baths were the only way they could wash. They had a tube system for urine relief, and the only things they were allowed to jettison overboard were fecal bags (usually used for critical care hospit-

Mark Green
Visions/Colorific!



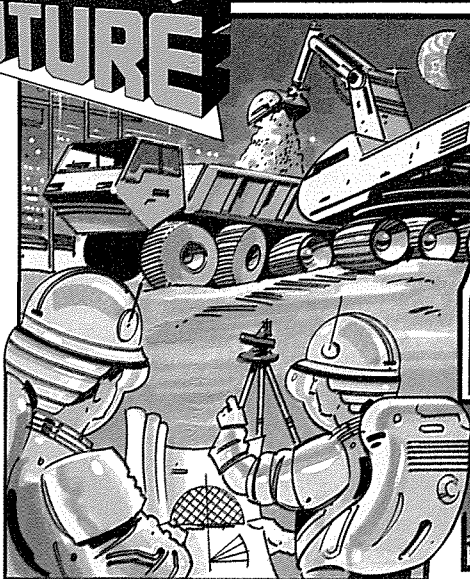
al patients). These went through a hatch in the floor.

Plenty of drinking water was taken on the trip to avoid dehydration and blood coagulation. Food came in sealed packets and a portable element was used to heat it.

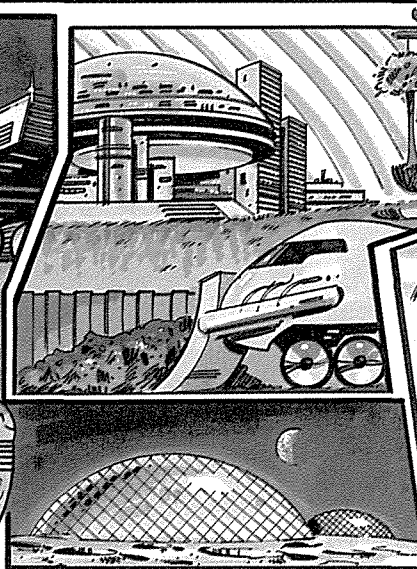
The workload only allowed about two hours sleep per day.

INTO THE FUTURE

SPACE FOR LIVING



▲ Man's quest to colonize other worlds will lead him to build cities within giant self-standing structures on the surface of the Moon and Mars.



▲ All the resources of planet Earth will have to be built into these 'geospheres' in order to create a self-sustaining eco-system in which life can flourish.



▲ Life inside would be a replica of life on Earth. Eventually, a generation will evolve that will regard the geosphere as home and Earth as the distant mother planet.



THE CUTTING EDGE OF LAND power is today, as it has been for the past fifty years, still the Main Battle Tank (MBT). Despite all the technical sophistication of a strike aircraft or nuclear armed missile it is land forces that must move forward, seize and hold ground if military operations are to reach a conclusion.

It has been said on more than one occasion that the era of the tank is over. First, battlefield nuclear weapons were going to render them obsolete, next it was hand-held infantry anti-tank guided weapons (ATGW). But then it was realized that nuclear weapons might not be used at all on the battlefield and, even if they were, that a tank's armour provided the best possible protection against the effects of a nuclear weapon.

Thermal imaging

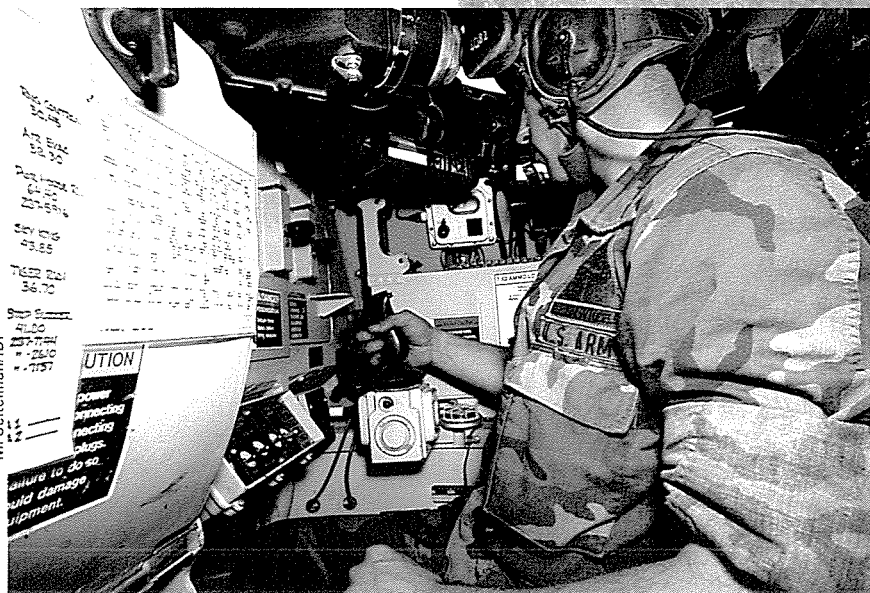
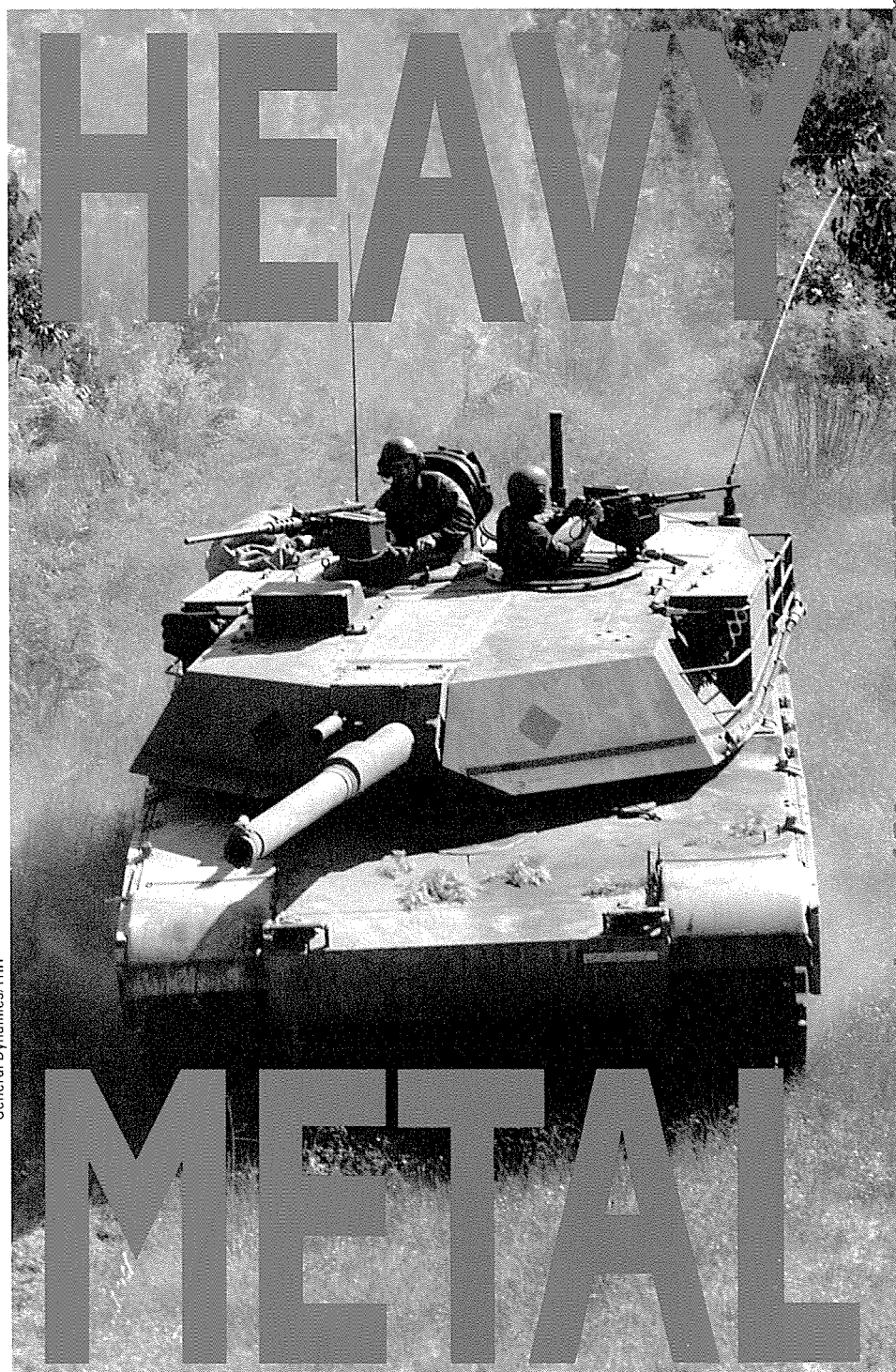
As for ATGW, although they can be very effective and are a serious threat to tanks, they certainly have not made the tank obsolete. Infantry ATGW have a relatively limited range which means that a tank can stand off and deal with them before they can hit back. Their warheads are relatively small and not always able to penetrate the thickest armour of a tank and their operators are vulnerable to artillery and fire from other tanks.

An ATGW can also be affected by obscurity — that is, during the missile flight, the operator may lose sight of his target because of battlefield smoke or because it has sought cover behind a hill or a wood. Although the latest Thermal

General Dynamics/TRH

Tanks, such as the American Abrams, are the supreme fighting vehicles, in the front line of all land-based warfare.

The driver of a US Bradley Armoured Fighting Vehicle steers with a pair of electronic joysticks.



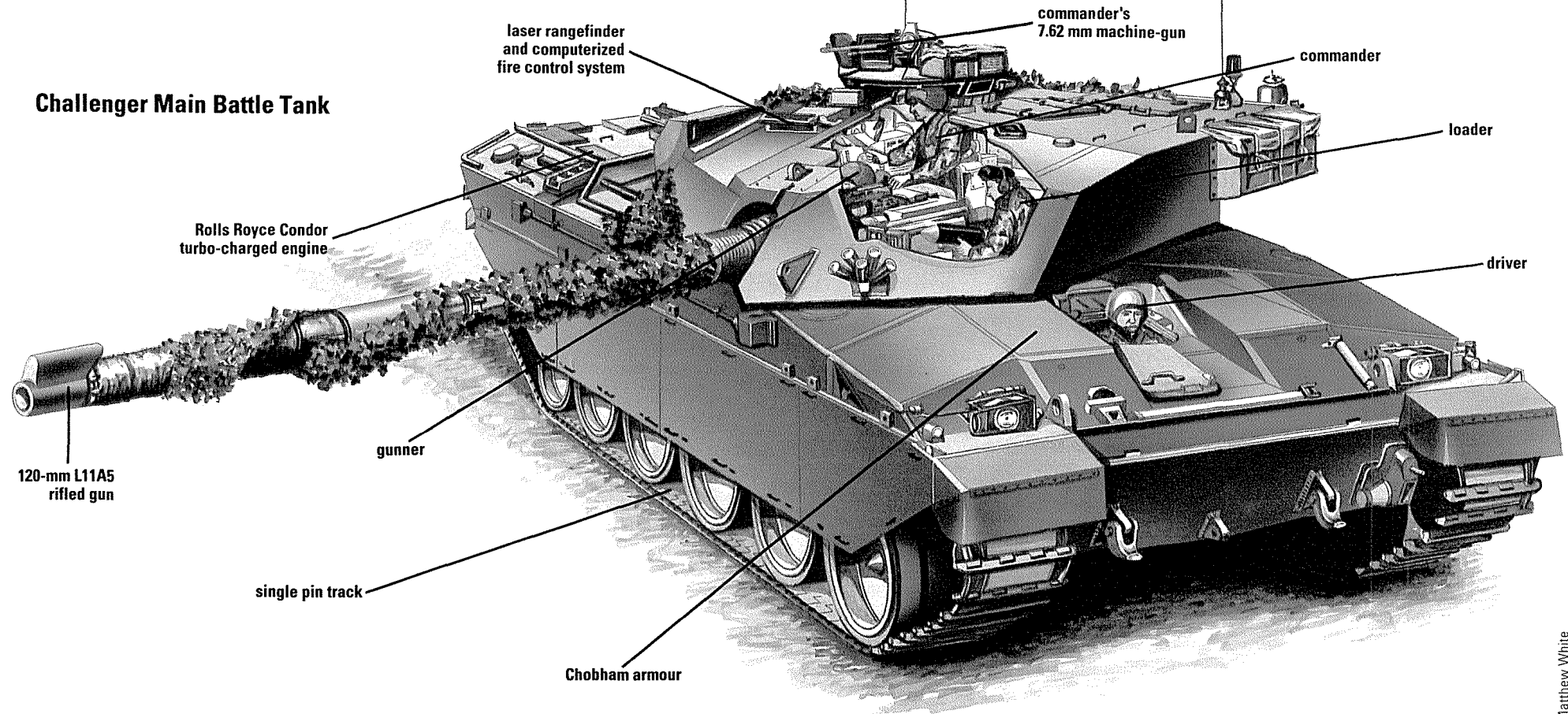
Imaging (TI) sights can see through smoke, man has not yet invented a way of seeing through hills! So, even though there are many threats to a tank, it remains the most potent weapons system on the battlefield.

The tank is not a complicated machine. It is basically a mobile protected gun platform. It works on the caterpillar principle with its rear spigot driven by a rear-mounted engine. The spigot drives the tracks which are mounted on six or seven wheels. The tank is steered by running one of the tracks faster than the other.





Challenger Main Battle Tank



Matthew White

The Challenger is the backbone of the British army's armoured force. The 120 mm rifled gun fires a kinetic energy round over 3,000 metres. This can penetrate armour, in a highly destructive manner, without any explosive charge.

The Russian Army is equipped with vast numbers of tanks. Western armies too have concluded that the most potent enemy of the tank is another tank and have invested vast sums of money in the development of highly sophisticated MBTs equipped with electronics and fire control systems.

But however sophisticated the technology, the designer of an MBT is faced with the old problem of striking the right balance between mobility, firepower and protection; the resulting mix reflecting national

traditions and a perception of how future wars might be fought. That perception, of course, is not static and, with a modern MBT costing over \$3 million and having a service life of 30 years, it is quite important to get it right!



Firepower

The British have traditionally emphasized the importance of protection and firepower at the expense of mobility in the design of their tanks. The result has been the Centurion, the Chieftain, and the

Challenger — all of them 55–60 tonne tanks, immensely well protected with thick armour and having powerful and effective gun systems.

But the British tanks are not agile. German tank design, on the other hand, has put a high value on mobility. The result is the Leopard 1 and Leopard 2. While Chieftain has a power to weight ratio of 19 hp/tonne (Challenger is slightly better than this) Leopard has a staggering power to weight ratio of 27 hp/tonne and a top road speed of

72 km/h at a combat weight of 55 tonnes! While British tanks are designed to be able to take more punishment, German tanks are designed to be able to avoid trouble in the first place.

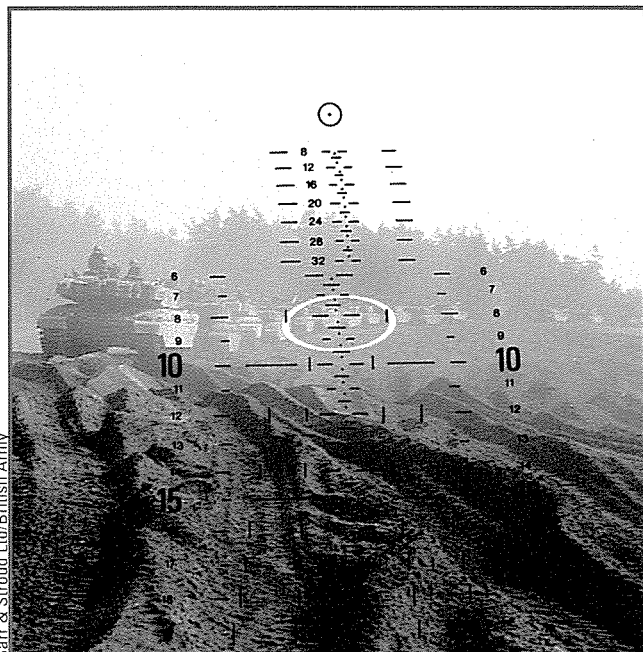
The Russians tend to favour the German approach. Their T-72 is a less capable tank than Challenger but certainly it is not hopelessly inferior and every year since 1978 the Russians have built more T-72s than the entire production run of Challenger.

The Western tank main armament

until the 1970s was the 105 mm calibre gun, the British L7 rifled gun of 1950s vintage being the prototype mounted in the Centurion. The German Leopard 1, the US M60 and the Swedish S Tank all mounted the highly successful 105 mm gun. The switch to 120 mm came in the 1970s in the form of the British rifled L11 in the Chieftain and Challenger, and the German Rheinmetall smooth bore Rh-120 gun which is fitted to the Leopard 2 and the US M1 Abrams Main Battle Tank.

Laser rangefinders

A gun is, of course, as effective as the ammunition it fires and the fire control system by which it is brought to bear on the target. World

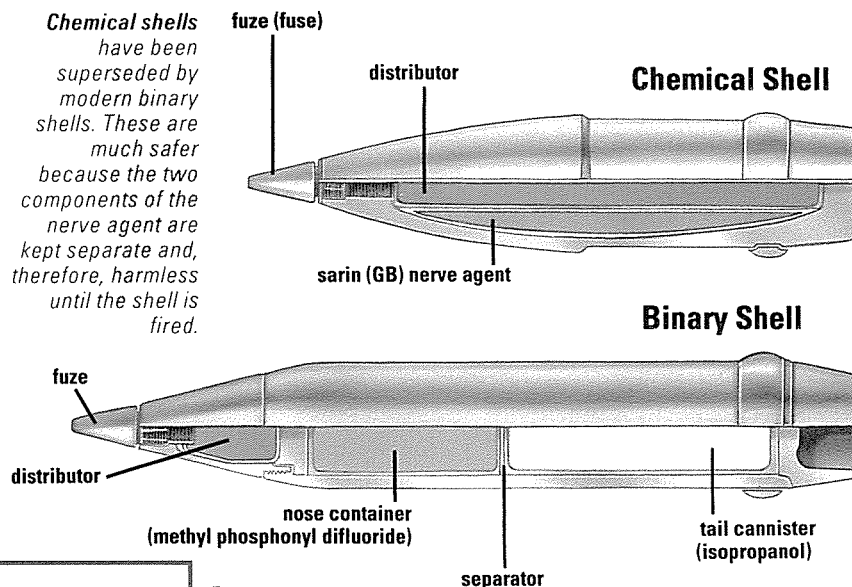


Barr & Stroud Ltd/British Army

War II fire control systems relied on an optical sight, which the gunner lined up on the target, determining range with an optical rangefinder and using a simple mechanical computer to determine elevation.

After the war the use of ranging machine guns firing tracer speeded up the process, but the big breakthrough was the application of laser rangefinders and the development of micro-electronic ballistic computers. Very accurate range data could now be allied with fire control data

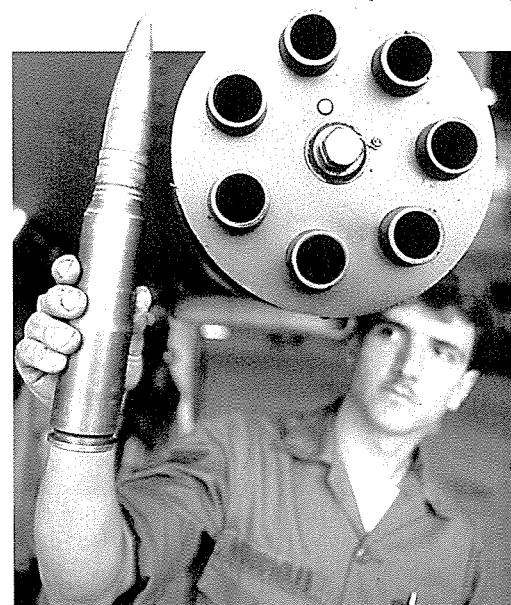
Chemical shells have been superseded by modern binary shells. These are much safer because the two components of the nerve agent are kept separate and, therefore, harmless until the shell is fired.



John Houghton

'Intelligent' fire control systems require the gunner only to aim at his target. The gun is then controlled automatically, guaranteeing an 80 per cent first hit rate – even when on the move.

The anti-tank shells of the A-10 aircraft are either armour-piercing rounds (as shown) or a high explosive round with a fragmenting steel case for area damage.



fed automatically into a stabilized gun laying system with, in some instances, automatic ammunition feed. This allowed firing on the move and much faster engagement sequences.

There are several distinct technologies in tank rounds themselves. While high velocity APDS (Armour Piercing Discarding Sabot) rounds are designed to destroy enemy tanks by smashing through their armour, HEAT (High Explosive Anti-Tank) rounds are designed to

achieve the same result by boring through armoured hulls.

APDS shot was developed by the British at the end of World War II. A round consists of a hard penetrator surrounded by a segmented sleeve or 'sabot' of lighter metal. As the round is lighter than a full calibre steel shot, muzzle velocity is increased while the full calibre absorbs maximum propellant energy. In flight the sabot falls away while the penetrator (made of dense material such as tungsten or depleted uranium) flies on at very high velocity.



Composite armour

HEAT rounds have hollow noses backed by a convex HE charge and detonated by a base fuse. They produce a devastating jet of superheated gas and metal moving at 20,000 metres per second on im-

An automatic stabilizing system keeps the Challenger's gun aimed, even when speeding across rough terrain.



pact. HEP (High Explosive Plastic) and HESH (High Explosive Squash Head) rounds splatter against the surface of the armour on impact, detonating against it to send a shock wave into the tank's interior and blasting off a scab of metal inside, to create the maximum internal damage.

Squash Head rounds can be countered by spaced armour – that is a gap between two layers of armour. The shock waves on the outside of the tank cannot be transferred directly to and through the second, or inner, layer of armour.

HEAT rounds are more effective, but they too have been countered

ably heavier than some of their predecessors: the Challenger at 61 tonnes, the Abrams at 54.5 tonnes, Leopard 2 at 55 tonnes and the T-80 thought to be about 48.5 tonnes.

Control systems

But design for protection is not limited to a tank's armour. Internal layouts are aimed at protecting critical systems and include fire suppression devices, blow out doors to deflect blast, special ammunition stowage and diesel fuel in self-sealing tanks to diminish the possibility of the tank 'brewing up' if hit.

But, despite all these precautions,

BEIJING TANK HERO



Rex Features

Although formidable on the battlefield, the tank is not the best of weapons for dealing with civil unrest – unless, that is, commanders are prepared to simply run over people. In Beijing, China, during the Spring uprising in 1989, a 19-year-old student, Wang Weilin stood in front of an entire column of tanks and succeeded in stopping them. Later reports claimed that the tank commander was demoted and Weilin arrested.

The Bradley M2, an armoured personnel carrier, designed to fight in close conjunction with the Abrams tank, is one of the fastest armoured vehicles, with a top speed of 66 km/h.



Mi Seitelman/IDI

by the development of composite laminations of armour plate using ceramic and other energy dissipating materials. Composite armour has given the latest tanks like Leopard 2, the M1 Abrams and the Challenger their characteristic slab-sided appearance.

Typical maximum armour thicknesses vary between 120 and 200 mm. The latest generation of tanks with compound armour are appreci-

tanks are killed on the battlefield. The best tank killer is undoubtedly another tank. Computerized fire control systems are the heart of a modern MBT.

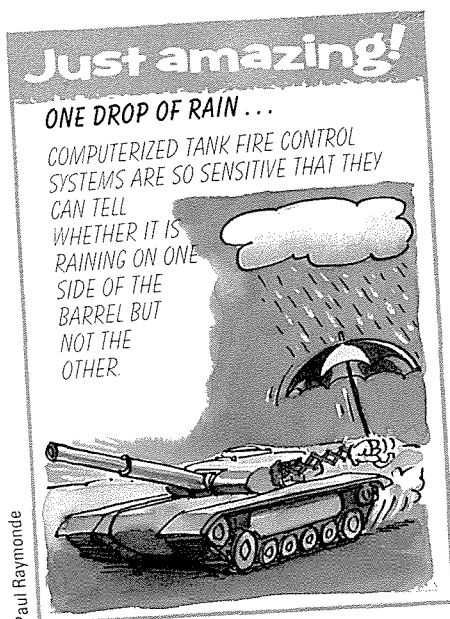
Sure fire

These systems can store information on ammunition type and are fed data by sensors that determine wind speed and direction, air temperature and pressure, barrel wear and temperature and even whether rain is falling on one side of the barrel – all factors which effect ballistic performance. This means that the all-important first round hit probability can be as much as 80 per cent when engaging a static target at a range of 3,000 metres or a moving target at 2,000 metres.

However, the infantry are able to protect themselves against tanks. Current ATGW systems require the operator merely to keep the target in the launcher's sights while electronics do the rest – gathering the missile into the control system's line of sight and generating automatic guidance signals to bring it in line with the target. These same missiles can be fired from attack helicopters. But, both the ground and air launched versions have HEAT warheads that cannot penetrate composite armour.

The only other way to put a tank out of action is with an anti-tank mine. These are designed to blow a track off a tank thus immobilizing it and making it an easy target either for other tanks or infantry.

TRH



Paul Raymond

An M88 Armoured Recovery Vehicle being used to change the powerpack (complete engine plus transmission) of a M60 tank. The M88 is a specialist maintenance vehicle that can also be used on the battlefield to recover stranded armoured vehicles.



KILLING MACHINES

THE GENERAL TERM 'GUNS' embraces everything from a handgun to a large artillery piece. A gun is defined as a weapons system which, by initiating a controlled explosion in a limited space, forces a high speed projectile out of a barrel at a target.

Guns can be direct fire weapons, aimed by the firer at a target that he can see himself. Or they can be indirect fire weapons, controlled by an observer who can see the target but fired by an operator who cannot.



Direct fire weapons

Rifles and pistols are direct fire weapons, which means that the trajectory described by their projectiles is relatively flat. On the other hand, projectiles from an indirect fire weapon such as a field gun will have a more curved trajectory, so that it can be fired over considerable distances and still arrive at the target.

The most extreme example of a weapons system with a curved trajectory is a mortar, which fires its projectile high into the air. It is the most suitable weapon for use in areas which are hilly or very built up.

Any projectile fired from a gun – whether it be a bullet in a rifle or a 155 mm shell in a self-propelled artillery piece – includes a quantity of propellant that is either built into the cartridge case or held within a separate bagged charge.



Controlled explosion

A firing mechanism, consisting of a trigger and a launcher, initiates a controlled explosion. The bullet is separated from the cartridge case by the force of the explosion and sent on its way along a rifled barrel or, in the case of fin-stabilised projectiles, along a smoothbore barrel. The empty cartridge is then ejected from the barrel.

However, in the case of automatic or semi-automatic weapons, there is one further use for the gases forcing the bullet along the barrel. Instead of just allowing these gases to be expelled from the end of the barrel after the exit of a round, as happens with single shot weapons, a small vent halfway along the barrel allows some of the gases to be funnelled into a chamber. Here, they drive back a piston which re-cocks the weapon ready to fire another shot.

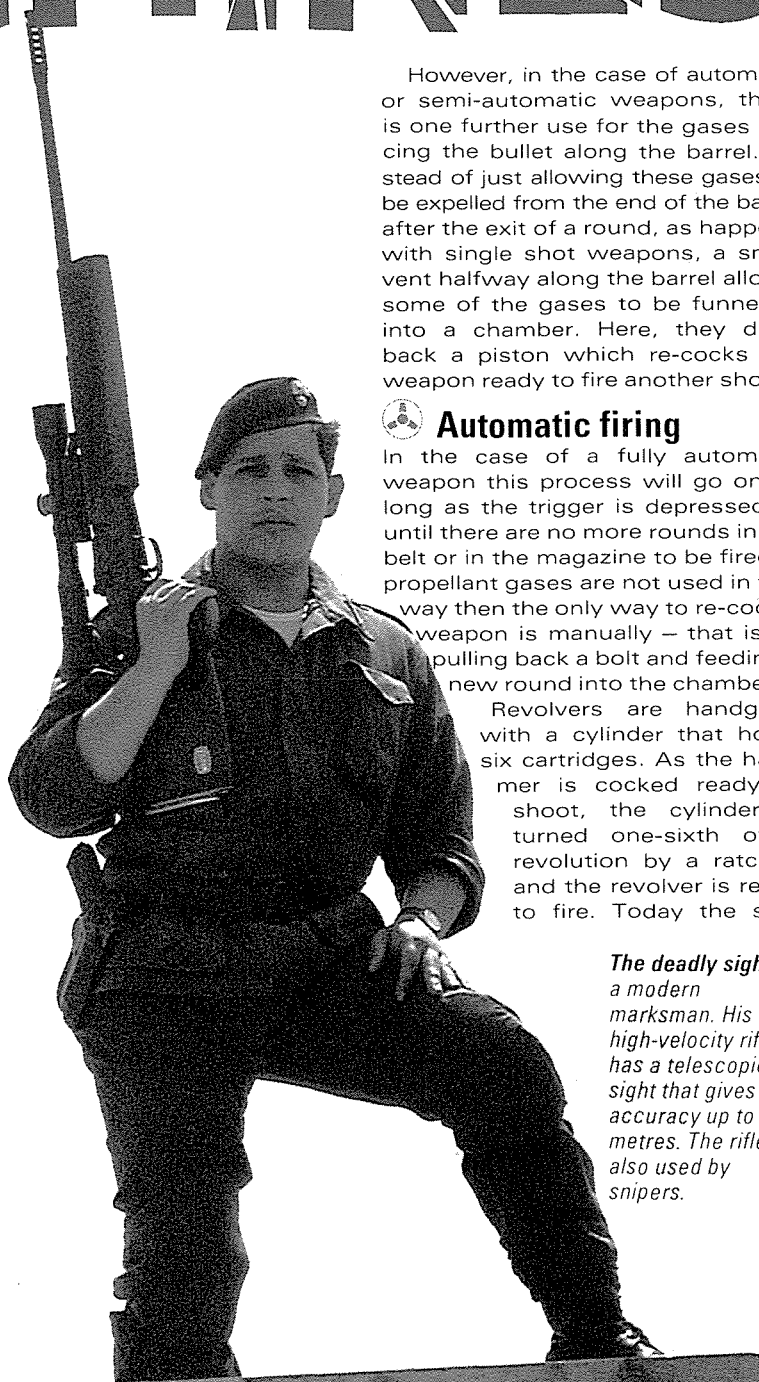


Automatic firing

In the case of a fully automatic weapon this process will go on as long as the trigger is depressed or until there are no more rounds in the belt or in the magazine to be fired. If propellant gases are not used in this way then the only way to re-cock a weapon is manually – that is by pulling back a bolt and feeding a new round into the chamber.

Revolvers are handguns with a cylinder that holds six cartridges. As the hammer is cocked ready to shoot, the cylinder is turned one-sixth of a revolution by a ratchet, and the revolver is ready to fire. Today the self-

The deadly sight of a modern marksman. His high-velocity rifle has a telescopic sight that gives him accuracy up to 1,000 metres. The rifle is also used by snipers.



loading or semi-automatic pistol has almost completely replaced the revolver. The first semi-automatic pistol was made by the Belgian Fabrique Nationale (FN) from a design by John Moses Browning in 1899, and has hardly changed since then. It has a magazine, or 'clip' of ammunition instead of a revolving chamber.



The British SA80 is considered to be the world's leading combat rifle. Light and compact, it is very easy to handle – but it is also powerful and accurate, thanks to a telescopic sight and low level of recoil.

The Kalashnikov AK is one of the most widely used assault rifles in the world. Since the Soviet Union launched the AK47 in 1947, it is thought that about 35 million Kalashnikovs have been sold around the world. It is capable of firing 600 rounds per minute at a range of up to 400 metres.



British Army

notoriety in the prohibition gang warfare in the United States in the late 1920s. It was later used widely by Allied troops in World War II.

Since then there have been many famous SMGs – the British Sten and Sterling, the German Heckler and Koch MP5A 3, the Israeli Uzi, the Italian Beretta 12S and various others. They are all used for short-range work in confined spaces, in situations where a great deal of firepower is quickly required.

Rifles

After a period of rapid development between 1870 and 1900, the infantryman's rifle became the characteris-

The Ingram M10 is very small and powerful. Without a suppressor, it can be hidden under a jacket, and is favoured by secret service agents.



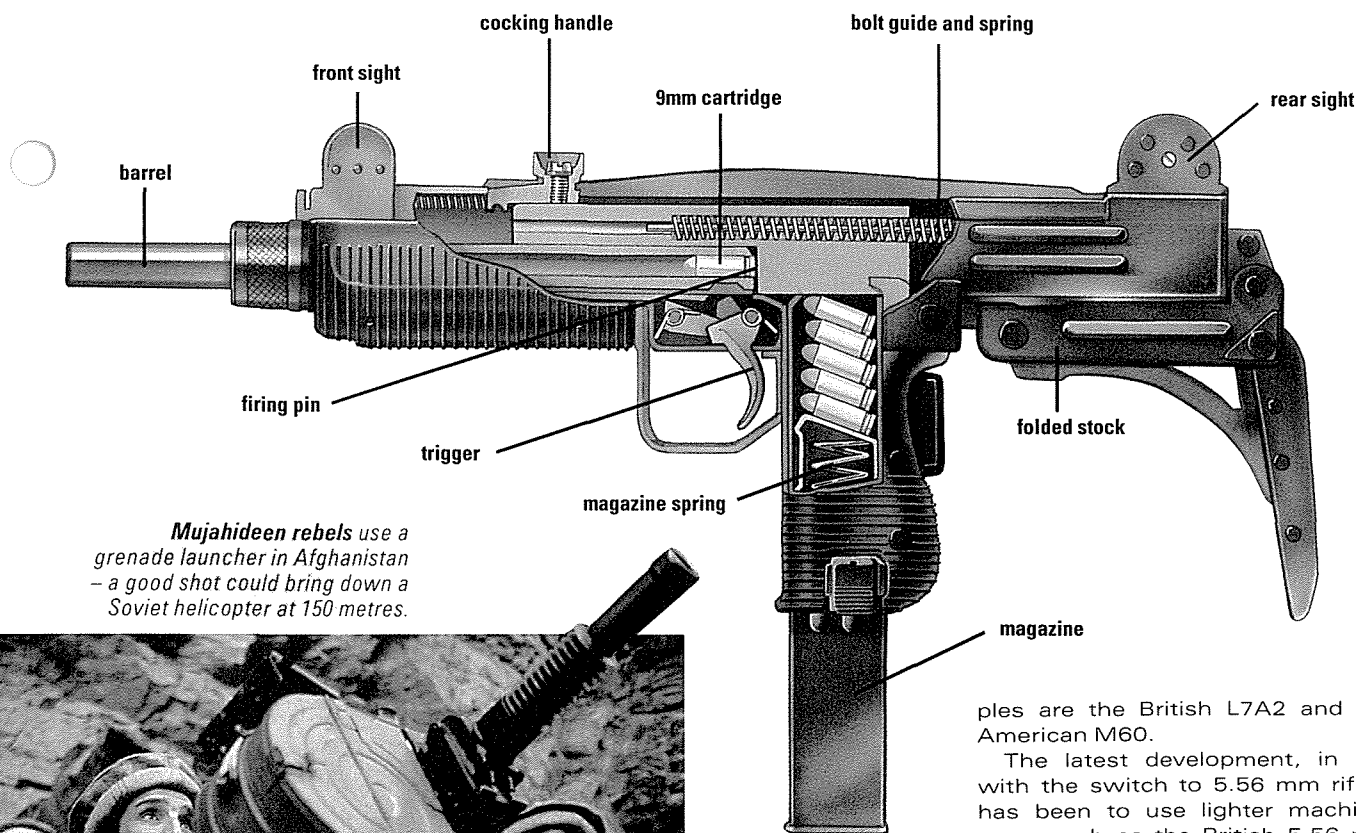
Robert Bruce/DI

The sub-machine-gun (SMG) appeared during World War I as a means of restoring the portable offensive firepower which the attacking infantry had lost in the mire of trench warfare. Perhaps the most famous SMG of all time was the Thompson, which first attained



The weaponry of the British police force comes in many shapes and sizes. The rifles are (from the top): Lee-Enfield L42A high-velocity sniper rifle fitted with night sight, Lee-Enfield L42A sniper rifle with telescopic sight, Heckler and Koch assault rifle, pump-action shotgun with full stock, and pump-action shotgun with pistol grip. The handguns are (from top): Smith and Wesson snub-nosed revolver, Ruger pistol, Smith and Wesson full-size revolver, Browning high-power pistol.

Rex Features



John Houghton

Mujahideen rebels use a grenade launcher in Afghanistan – a good shot could bring down a Soviet helicopter at 150 metres.

ples are the British L7A2 and the American M60.

The latest development, in line with the switch to 5.56 mm rifles, has been to use lighter machine-guns such as the British 5.56 mm SW, which are easier to use.

A man can only throw a grenade about 30 metres, but the latest grenade launchers can project them up to 400–800 metres. The most

The Uzi sub-machine-gun is simple, reliable and lethal. It is used by armies everywhere, including the British SAS and the US Special Forces. It was designed by Uziel Gal for use by Israeli tank troops, so it is very light and short. The revolutionary 'wrap-around bolt' allows the short gun to house a long barrel.

Quinn-Emmet Pictures

PLASTIC BULLETS

Used mainly for riot control, plastic bullets rarely kill, but can knock people out. They are large and blunt-ended projectiles made from plastic and fired from special rifles. Unlike pointed bullets, they should not pass through flesh. But they can cause nasty injuries (below) and at close range can be fatal.

tic bolt action magazine weapon firing a powerful round of roughly 7.92 mm calibre.

This remained the case until the end of the Second World War when the self-loading rifle (SLR) began to replace the vast number of bolt action rifles produced during the war. During the period 1955–1980, the world's armies were equipped with well known SLRs such as the Belgian FN, the West German Heckler and Koch G3, the US M14 and, perhaps the most famous of all, the Soviet Kalashnikov AK-47 assault rifle.

Lighter weapons

Then, as infantrymen were saddled with an ever-increasing load of sophisticated equipment, it was realised that the high-powered, long range and relatively heavy 7.62 mm SLRs were an unnecessary luxury.

The US Army developed the Armalite AR-15 instead. It used a

completely new 5.56 mm cartridge firing a bullet at very high velocity (1000 metres per second) but at an impulse low enough to make sustained automatic fire controllable. It weighed only 2.7 kg and its magazine held 45 rounds. As a completely new concept in infantry rifles, the Armalite spawned many imitators including the Austrian Steyr AUG, the French FA MAS, the West German Mauser 911 and the British SA 80.



The machine-gun

The terrible slaughter during the trench warfare of World War I in 1914–18 resulted directly from the killing power of the machine-gun.

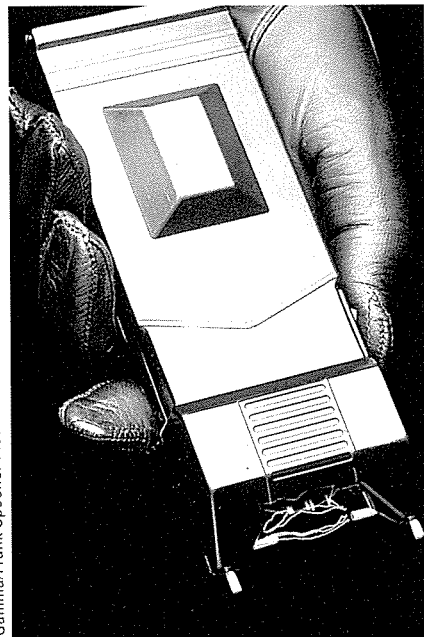
Today heavy machine-guns are really only used in an anti-aircraft role. Until very recently the tendency has been to use general purpose machine-guns (GPMGs) for both attack and defence. These are generally 7.62 mm calibre. Exam-

Jeremy Nicholls/Impact Photos



accurate of them launch grenades through rifled barrels.

The US pioneered this type of weapon with the 40 mm M79 grenade launcher, which looked like a single barrel combat shotgun. A well-trained operator could put grenades through a window of a house at 150 metres. The US Army replaced the M79 with the M203 40 mm



Gamma/Frank Spooner Pictures

grenade launcher which is small enough to fit under the barrel of an M16A1 assault rifle.

Mortars are simple yet effective weapons. The bomb has a propellant charge in its tail and when dropped in the tube by hand, it strikes a firing pin. The charge is detonated and the bomb is projected. The simplicity and ease of loading allows a very high rate of firing, and the steep angle of descent creates a near-circular lethal area.

Until recently mortars have been



Long-range artillery guns can knock out tanks. This one fires 105 mm shells.

British Army

The stun gun sends out a short, sharp shock that scrambles the victim's nervous system, causing temporary paralysis.

used mainly to attack men in the open but a British system called 'Merlin' employs the 81 mm mortar to attack tanks from above, where their armour is weakest.

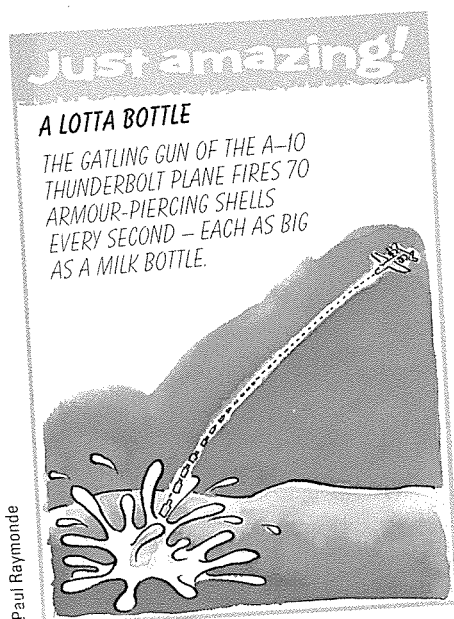
Artillery pieces can be broadly categorized into field, heavy and self-propelled artillery. Field artillery guns vary between 105–155 mm calibre, bringing devastatingly accurate firepower up to 30 km.

Finally, except for aerial or amphibious weapons, nearly all systems are being put on tracks, which increases tactical flexibility. The direct fire weapon – whether it be a rifle or a heavy artillery gun – has many valuable years service ahead of it. While directed energy weapons such as lasers may be developed so that they can be used on the battlefield, guns firing bullets or shells will remain – although the method of delivery will become quicker, more accurate, and better co-ordinated, and they will take place over longer ranges.



British Army

Hi-tech war games are used to train troops for real combat situations without putting them at risk. Their rifles are adapted to fire harmless laser beams and the soldiers wear a special receiver on their helmets and bodies. If they are 'hit', the equipment registers them as 'dead'.



Paul Raymond

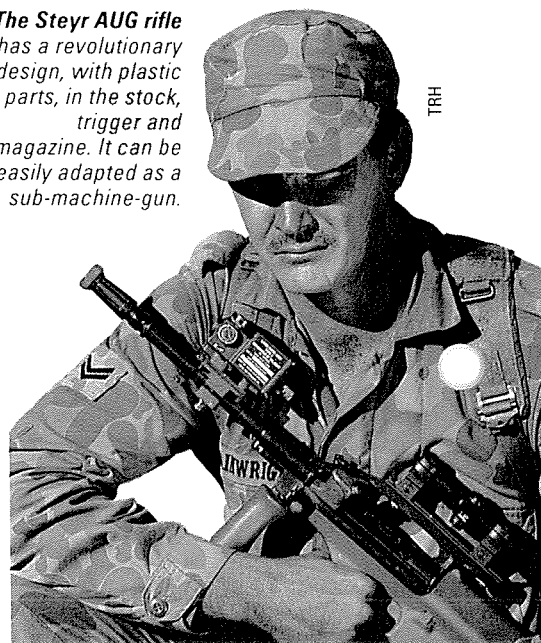
Heavy artillery is used to bring sustained firepower at longer ranges to pulverize the most determined of defenders. It is also used to fire so-called 'tactical nuclear weapons'. Although the US Army developed 203 mm and 175 mm guns to fulfil this role, nuclear weapons can now be packed into 155 mm artillery shells.



Longer range

The latest developments in field artillery are longer range, by improvements such as rocket-assisted shells, increasing lethality by applying precision terminal guidance to artillery shells, and co-ordinating firepower more efficiently with computerized systems.

The Steyr AUG rifle has a revolutionary design, with plastic parts, in the stock, trigger and magazine. It can be easily adapted as a sub-machine-gun.



TRH



THE SEA WOLVES

BENEATH THE SURFACE OF the sea move the submarines of the world's navies. 'I come unseen' is the motto of the British Royal Navy's submarine service.

There are three main types of submarine in action today:

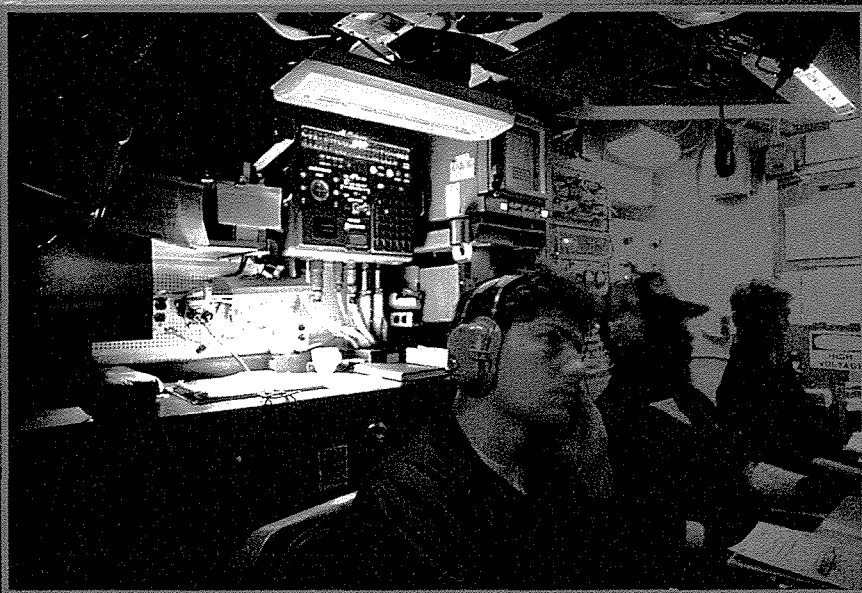
- Nuclear-powered submarines (SSBNs) armed with nuclear ballistic missiles that can stay underwater for months
- Smaller nuclear-propelled attack submarines (SSNs) that can also remain submerged for long periods
- Diesel-electric patrol boats (SSKs) that must send up a snorkel tube at regular intervals to take in air

Richard Cooke

for the engines which recharge their batteries.

Nuclear submarines designed to fire long-range ballistic missiles are operated by the USA, and the USSR, Great Britain, France and China. Their ability to avoid detection by staying underwater for months, if necessary, gives them protection from a nuclear attack not enjoyed by a fixed missile launch site on land.

HMS Repulse, a British Polaris submarine, carries 16 inter-continental nuclear ballistic missiles, each with a range of 4000 km.



At the sonar console aboard the Los Angeles class attack submarine USS La Jolla, sonar technicians man their underway watch stations, 'listening' for the approach of another submarine or a ship.

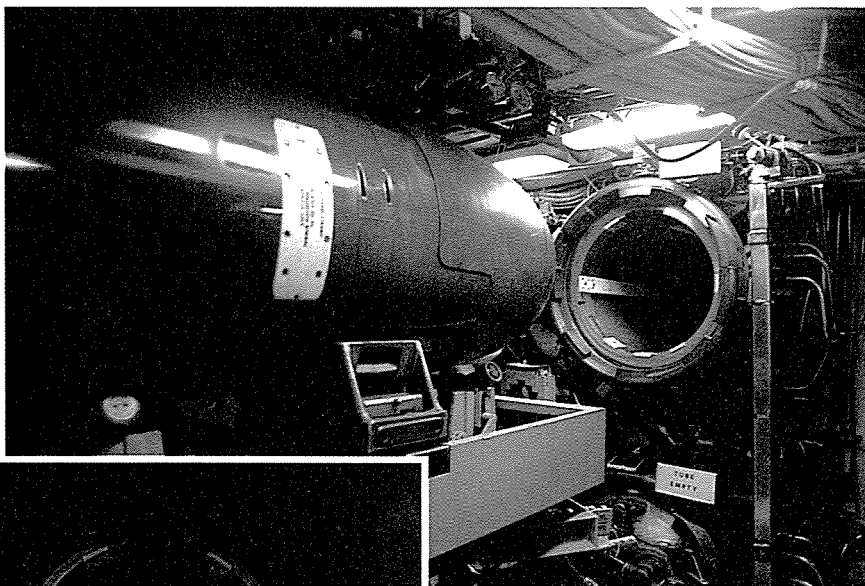


SSBNs cannot be eliminated in a first strike — yet they can mount a devastating counter-attack on a nuclear aggressor, which makes them a very effective nuclear deterrent. SSBNs include the world's largest submarines, the Russian 'Typhoon' class; at 170 metres long, each one is the length of two and a half jumbo jets placed end to end.

Big subs go faster and travel

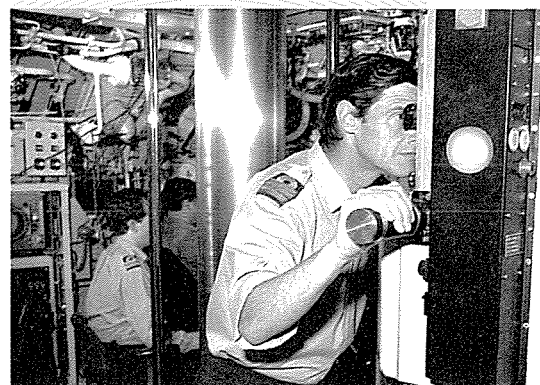
Initial contact might be made via a very low frequency radio signal that could only be picked up by a submarine 10–20 metres below the ocean's surface. Then the submarine would come closer to the surface to receive detailed orders.

SSNs — nuclear-powered attack submarines — are 'hunter-killers' of enemy ships and submarines. They are quiet, fast and easily manoeuvrable. The Russian Alfa class SSN,



The Mk 48 torpedo, carried aboard American *Los Angeles* class hunter-killer subs, is a very accurate heavyweight, wire-guided torpedo — said to be the best in the world. Stored on racks, torpedoes are fired at enemy ships and subs from launch tubes (left).

THE SUB'S EYE



Royal Navy Photograph

In order to positively identify a target, it is necessary to see it, which is why submarines have periscopes. A periscope allows the captain to have a 360° magnified view of the surface of the sea while his submarine is still submerged. Angled mirrors at the bottom and top of the periscope give the observer the horizontal view he needs for surveillance. Once a target has been fully identified, the periscope is lowered, and action is taken.

deadly earnest. When Argentinian troops invaded the Falkland Islands in 1982, SSNs arrived long before the British Task Force and enforced the exclusion zone around the Islands. The sinking of the Argentinian cruiser the *Belgrano* by HMS *Conqueror* is the only real attack ever made by a nuclear powered submarine.

In the age of nuclear-powered submarines, diesel-electric submarines, still fulfil important roles. They are less expensive, quieter and

at greater distances than smaller ones, and have the space to carry more weapons. The British Royal Navy's three SSBNs (*HMS Resolution*, *HMS Repulse* and *HMS Revenge*) each carry 16 Polaris nuclear missiles. The Trident SSBN HMS *Vanguard* is fitted with 16 missile tubes.



Missiles

The latest submarine launched ballistic missiles (SLBMs), such as the US Trident II D-5 (to be used by Britain as well), promise to be as accurate as land-based missiles. As a result, both submarines' navigation systems (called the Ships Inertial Navigation System — SINS) and navigation satellites, which provide position fixes for both the launch submarine and the missile in mid flight, have had to be upgraded.



Launch sequence

How do instructions to fire a missile reach a submerged nuclear submarine? A launch order would arrive as an Emergency Action Message. Only by mating this with its coded counterpart in the captain's safe could a launch sequence begin.



Hatches pulled back reveal eight missile launch tubes aligned behind the conning-tower on an *Ohio* class submarine — the latest American nuclear-powered sub. Each tube holds four Trident 1 C-4 submarine launched ballistic missiles.

known as 'golden fish', can dive to 760 metres and reach a top speed of 90 km per hour.

Both the USA and Russia have large fleets of hunter-killer submarines with the range and endurance to wait near the enemy's home ports and stalk their prey to the deep ocean patrol areas. The British Royal Navy has 12 SSNs.

Great Britain has the only navy with experience of using nuclear-powered attack submarines in

smaller than nuclear submarines. Nuclear-powered boats are extremely expensive — only the biggest navies have them. The cost of an SSN like the US Navy's 9250 tonne *Seawolf* is around one billion dollars.

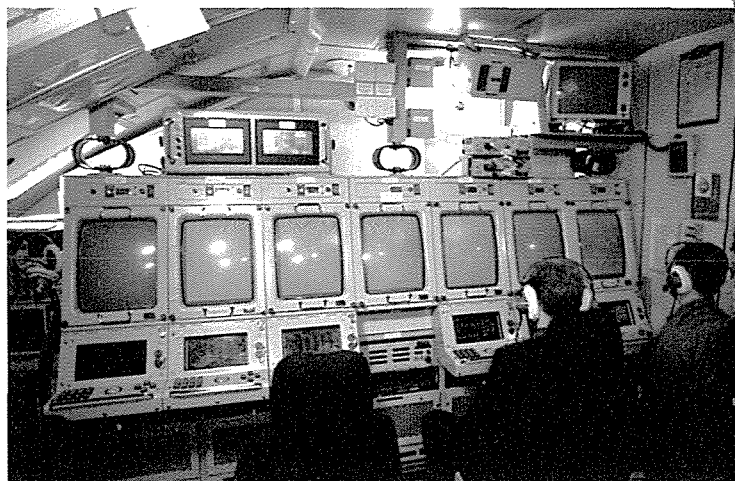
Diesel-powered boats are useful for coastal defence in shallow waters and ideal for secret reconnaissance and minelaying, because they are smaller than nuclear-powered subs and can move along very



BIG FISH

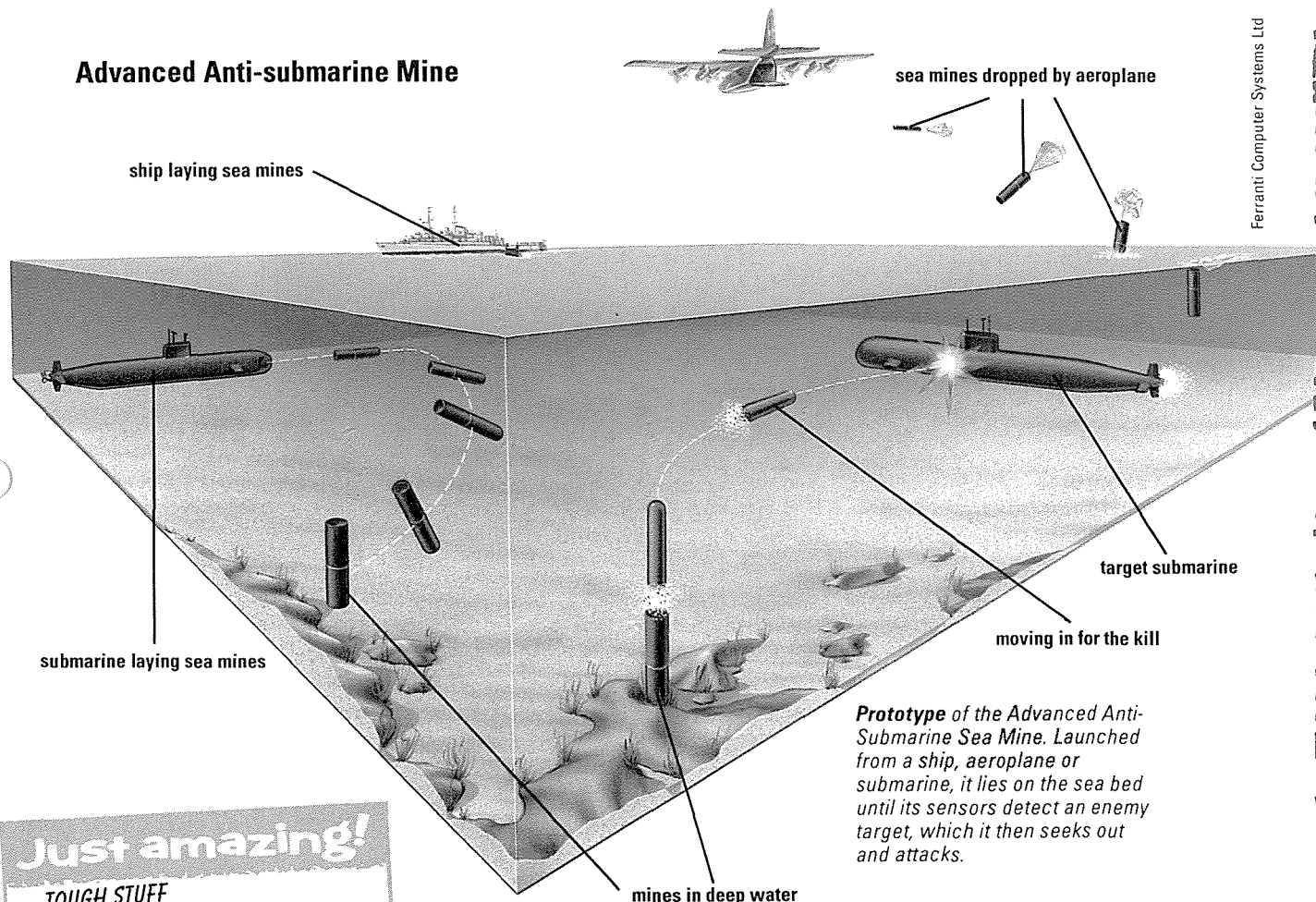
In 1982 the crew of the trawler *Sharelga* were fishing in the Irish Sea, when they suddenly found the boat being dragged along at great speed by an unseen force. The boat overturned and the crew were lucky to be rescued by other fishing boats. Since 1980 there have been a series of similar incidents. Trawlers involved were often in sea lanes through which submarines frequently moved, such as 'Submarine Alley' between Northern Ireland and the Scottish coast and the subs were getting entangled in their nets. It has been speculated that subs also caused freak waves that sank other boats.

Sonar sensors on *Polaris* submarine HMS Resolution – an electronic system that detects other ships and submarines. Active Sonar sends out sound waves that are bounced back off any solid objects. Passive Sonar can 'hear' the smallest sounds without giving away the presence of the hunting submarine.



Advanced Anti-submarine Mine

Marconi Underwater Systems



Ferranti Computer Systems Ltd

Prototype of the Advanced Anti-Submarine Sea Mine. Launched from a ship, aeroplane or submarine, it lies on the sea bed until its sensors detect an enemy target, which it then seeks out and attacks.

Just amazing!

TOUGH STUFF

THE PRESSURE ON THE HULL OF A SUBMARINE AT A DEPTH OF 300 METRES IN SEA WATER IS ABOUT 30,000 KG PER SQUARE METRE – EQUIVALENT TO SIX 5 TONNE ELEPHANTS ON AN AREA THE SIZE OF A DESK TOP.



Paul Raymond

quietly, so that it is difficult for an enemy submarine's sonar sensors to 'hear' them. They can enter enemy harbours undetected and destroy enemy shipping with mines and miniature torpedoes. Submarines with diesel propulsion are normally equipped with six or four bow torpedo tubes.

Deadly exports

A number of nations, including France, West Germany, Italy, Japan and Sweden also construct their own diesel-electric submarines. In addition, West Germany has exported some twenty of their Type

209 submarines to the navies of Argentina, Columbia, Ecuador, Greece, Indonesia, Peru, Turkey and Venezuela.

Dive! Dive!

Submarines submerge by filling large ballast tanks with water and then, when they want to surface, blowing that water back out of the ballast tanks under pressure. A normal surfacing is achieved gradually by selective blowing of ballast tanks, but submarines can surface very quickly indeed in an emergency by blowing all their ballast tanks at once. They can control their depth, to some extent, by varying the angle of the diving planes (horizontal fins) attached to the body of the sub.



SUB REVOLUTION

Italian engineers have invented a new non-nuclear submarine propulsion system called GST – gaseous storage in a toroidal hull. A GST submarine is made up of a series of pipes (or *toroids*) within which the prime energy source, stored in the hull, is gaseous oxygen under very high pressure. The Italian Navy now has its first GST midget submarine (9.65 metres long), called 3GST9. GST has many advantages:

- a toroidal hull is five times as strong as one made from steel plates
- more space for weapons
- a much longer range than conventional diesel-electric craft – the larger GST mini-sub, 23–27 metres long, are able to travel almost 4000 km without nearing the surface to take in air.
- it is relatively cheap – a mini-sub could cost about \$36 million, compared to \$330 million for a British Trafalgar class attack submarine.

In peacetime, submarines are in fact very safe, but accidents can happen. The most serious thing that can go wrong is for the hull to be damaged, allowing water to get inside. This is one of the greatest fears of every submariner.

Fire hazard

The hull is divided into watertight compartments so that only those sections directly damaged will flood with water. But if enough sections are flooded, the submarine will sink. Another hazard is the possibility of a fire breaking out in the engine room. This has happened recently to several Soviet submarines. In each case the sub was forced to the

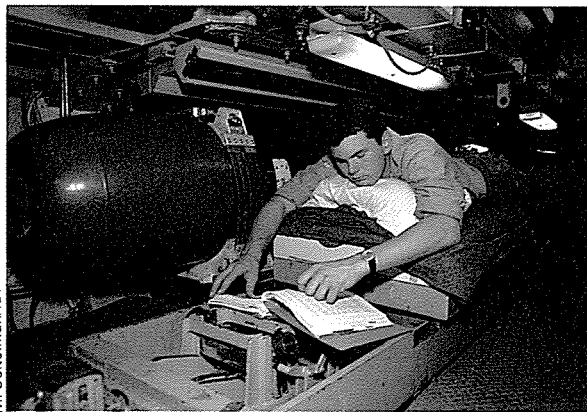
surface, where the crew had to wait for rescue.

How can the crew escape if the submarine is crippled and cannot surface? Only if the submarine is airtight and stable, resting on the sea bed at not too great a depth, can the crew use the escape hatches. The men, one by one, climb into the escape compartment, don breathing apparatus, flood the chamber and swim to the surface.



Escape

However, the human body cannot withstand the pressure at extreme depths. Also, surfacing too quickly produces the 'bends' (when air bubbles enter the blood stream), which cause a fast and painful death, unless the sufferer is



Mr Seitelman/DLI

Fire put the Soviet nuclear cruise missile submarine Echo II out of action. It had to be towed back to its base at Murmansk on the Barents Sea.

Space is so scarce aboard the Los Angeles class attack submarine USS Cincinnati that crewmen have to bunk down beside the torpedo storage racks.

put into a depressurization chamber immediately.

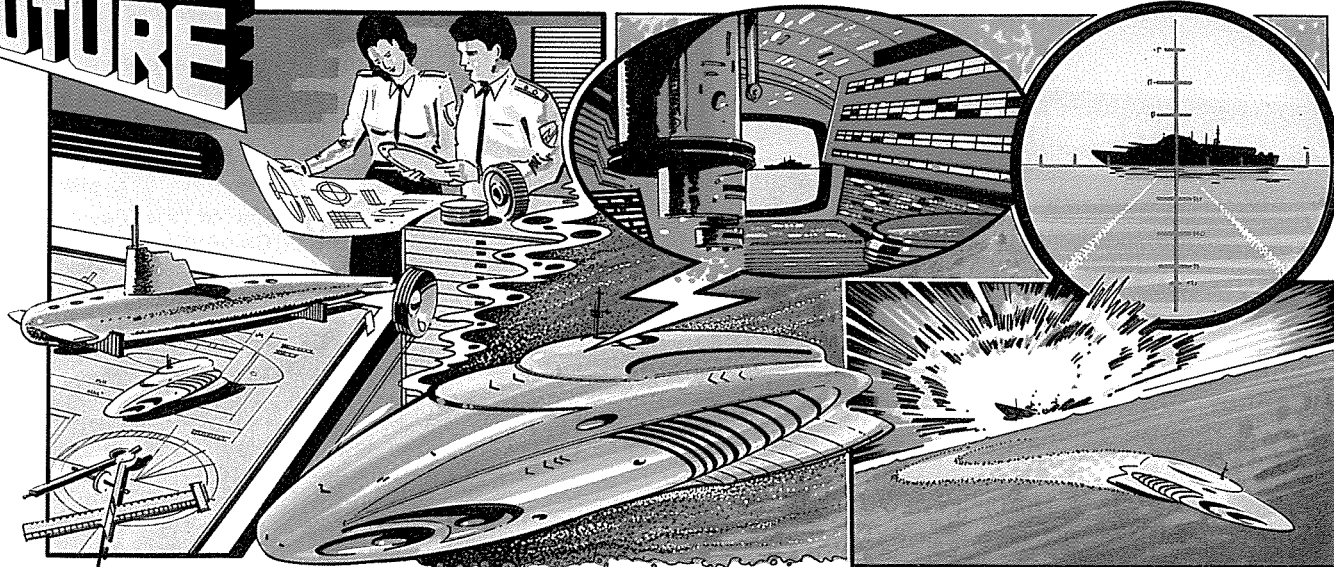
The only other hope would be rescuers approaching in a craft capable of taking the men off the sub. The United States Navy and British Royal Navy are equipped with submersibles – miniature subs able to

dive to the crippled sub and lock on to it, allowing men to climb through an escape hatch from one vessel to the other.

In the future, submarines may well carry 'submarine lifeboats' – collapsible vessels that can travel to the relative safety of the surface.

INTO THE FUTURE

SMALL – BUT DEADLY



▲ As detection systems become more advanced, submarine designers will make their craft almost invisible. Subs will be much smaller than they are at present.

▲ Such craft will be totally silent in operation and without a human crew. They will be controlled by an 'intelligent' on-board computer, communicating with base.

▲ When the computer detects an enemy ship the sub will move in for the kill, invisible to its prey. Then the sub will sail away, continuing its silent search.

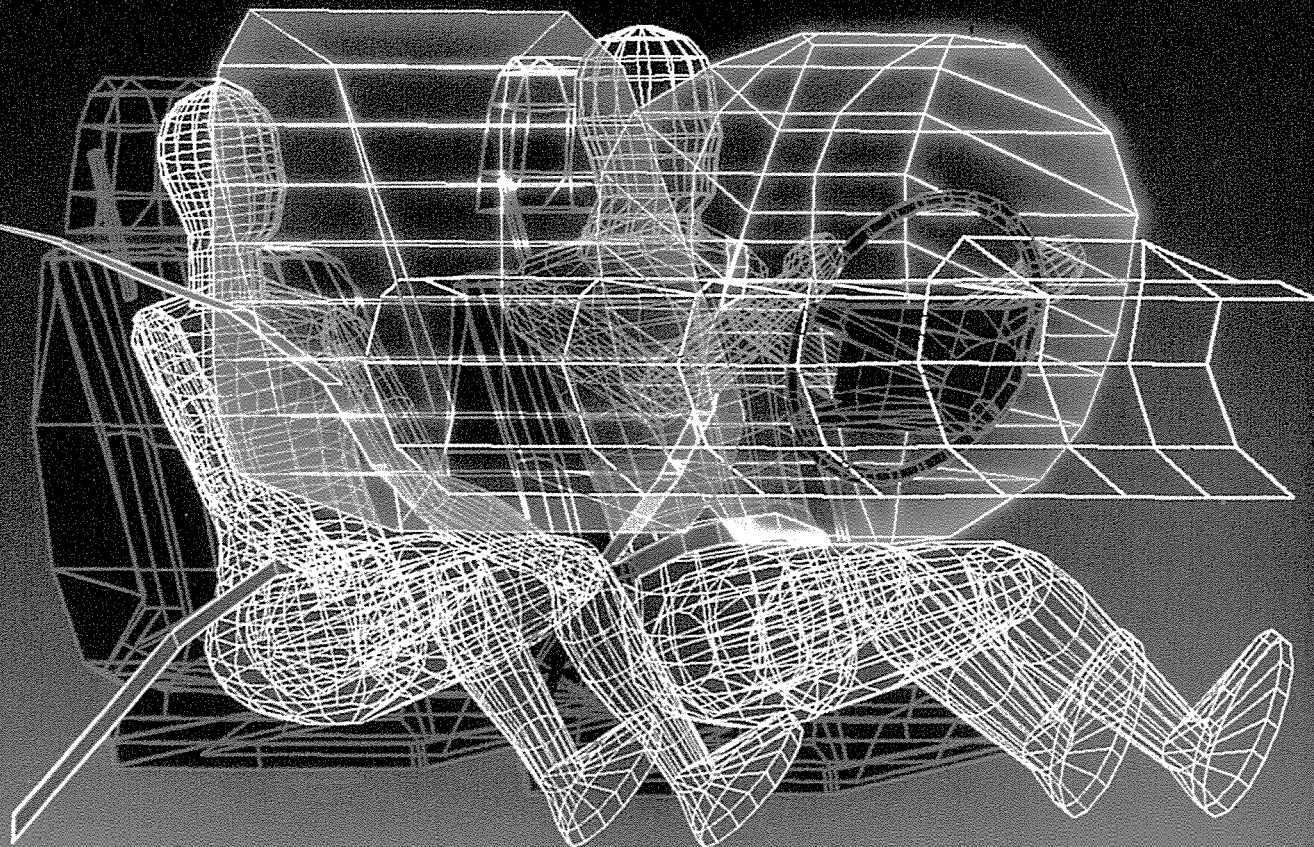


COLLISION ALERT

ANTI-LOCK BRAKING

BODY RESTRAINTS

SAFETY AT



SPEED

Mercedes-Benz (United Kingdom) Ltd

ALL ASPECTS OF CAR DESIGN have been revolutionized through the use of powerful computers. A major challenge to car manufacturers has been to reduce the overall weight of vehicles – and so boost fuel economy – while improving passenger safety

If his vehicle goes out of control, say on a wet or icy road, a driver may panic and slam his foot down hard on the brakes. Normally, this would result in the wheels locking, the tyres becoming like skis, and the car sliding even further out of control. With the development of anti-lock braking systems (ABS) this can now be avoided.

ABS is the first electronically controlled automatic traction system.

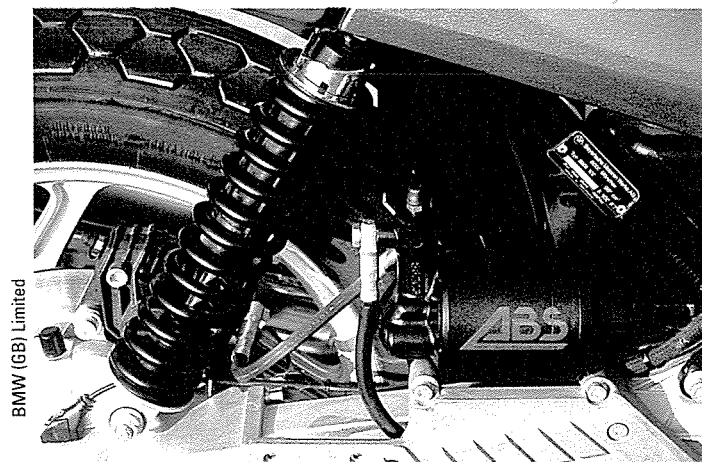
Computers enable car designers to experiment with new ideas. Here Mercedes-Benz simulate airbags to protect the heads of both driver and front seat passenger

Road accidents feature in many films. This spectacular stunt took three days, six cameras, 13 stuntmen, and \$60,000 dollars to produce a final edit of 3 minutes.



When a microcomputer linked to the braking system senses that wheel lock is about to occur it takes over automatically from the driver. It causes the brakes to 'pump' up to 10 times a second – far faster than

Anti-lock braking systems – on motor bikes as well as cars – automatically prevent wheels locking during skidding.



BMW (GB) Limited

any human could achieve. The split-second releases of pressure keep the wheels turning even as they are slowed, so that grip with the road is maintained.

A test dummy shows the relative positions of driver and fully inflated air-bag within a fraction of a second of a simulated head-on crash.



Safety features available in new cars as standard or options include: zones that absorb the impact energy of a collision by crumpling gradually; fuel tanks located in front of the rear axle to minimize fire risks; automatic anti-lock braking systems to prevent wheel lock; padded interior fittings and galvanized door sills to reduce the rust which might eventually weaken the steel safety cage.

Many other electronic-automatic safety systems are beginning to be incorporated into car design. At Mercedes-Benz systems include ASD, ASR, and 4MATIC.

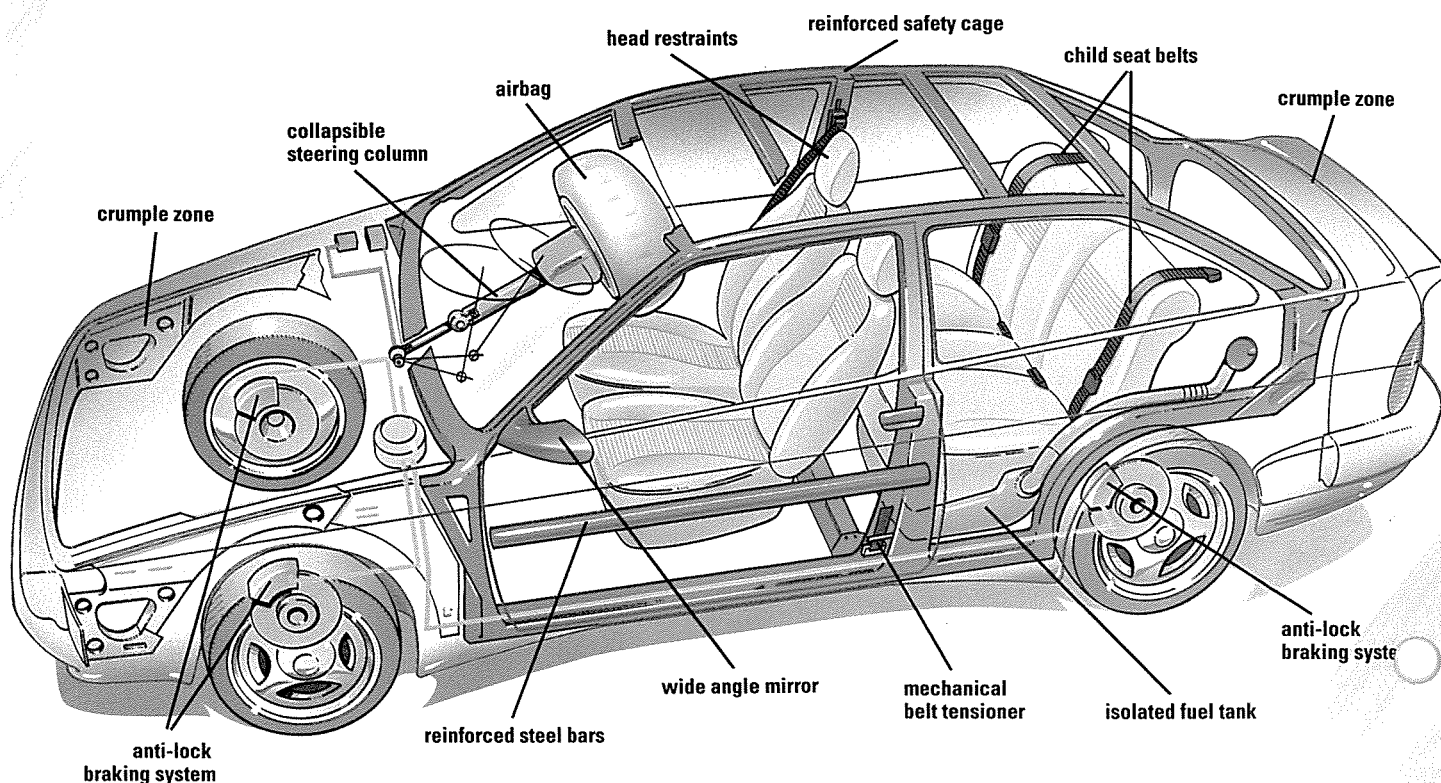


Computer take-over

The ASD microcomputer system senses when one of the driven wheels is about to skid and automatically switches drive to the other

driven wheel. ASR prevents skidding in the driven wheels when the driver accelerates. The 4MATIC system switches automatically to 4-wheel drive whenever it senses that this would improve traction – during fast cornering, for instance. All of these systems are connected to light warnings on the dashboard to tell the driver when they are operational. They assist the driver rather

Volvo Concessionaires Ltd

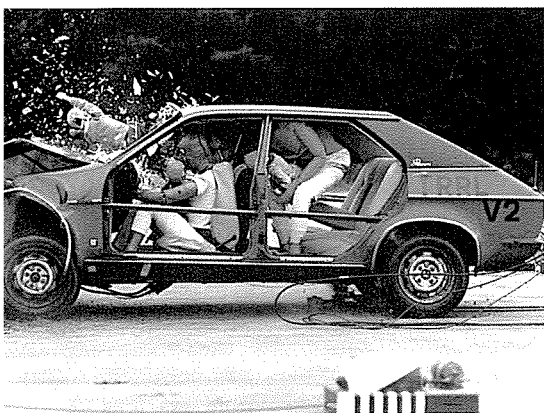


than disrupt normal braking.

In a high-speed crash, two factors are crucial in avoiding serious injury. First, there must be some way to prevent the passenger compartment from being crushed or seriously damaged. Second, those inside need to be restrained from flying out of their seats and through the car's windscreen.

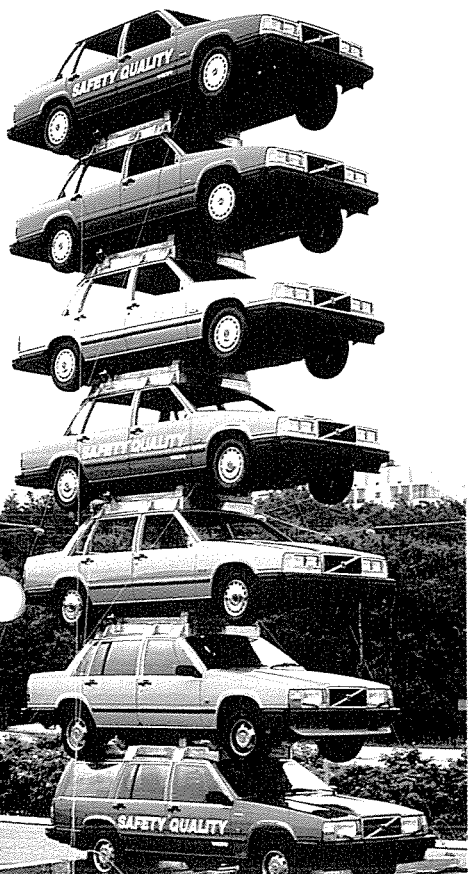
Safety cage

Many new cars now have a rigid steel safety cage as part of their body structure. Also steel bars run across the doors to protect passengers from the side impacts. Volvo's



In a serious accident a person may be thrown forward with a force of three tonnes. Wearing a seatbelt is the best precaution against injury.

Traffic Accident Research Unit has found that in accidents where drivers and passengers are injured, side collisions are second only to frontal impacts.



Transport & Road Research Laboratory

Clunk-click

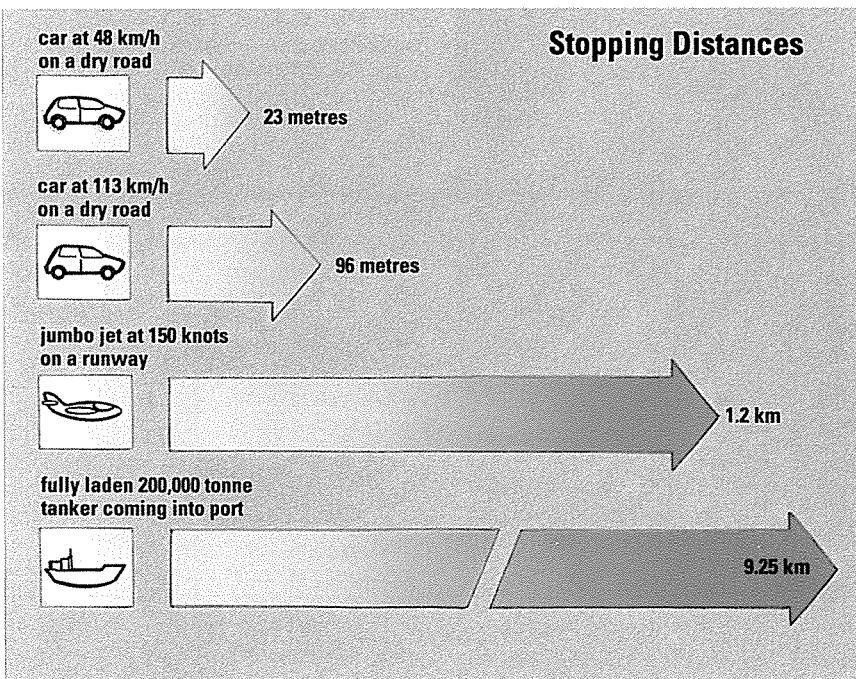
In many countries it is now illegal for anyone to ride in the front of a car without wearing a seat belt. And in some, including Britain, back seat passengers must also wear seat belts or safety harnesses. Without this form of restraint, passengers would become projectiles if the car were to suddenly stop. A crash into a rigid barrier at a speed of just 20 km/h is equivalent to a fall from a height of 1.6 m.

Child protection

Unrestrained children on an adult's lap are at great risk. Tests have shown that the maximum collision speed at which an average adult (wearing a seat belt) can prevent a child being thrown forward is about 5 km/h. During a collision, if the adult is not restrained by a seat belt, he or she will be thrown on to the child in front. At a speed of 50 km/h the adult's body will crush the child with a force of three to five tonnes.

The three-point seat belt is probably the most important life-saver for car occupants since the inven-

A publicity stunt demonstrates the strength of the steel safety cages in Volvo cars. If a Volvo rolls over, the cage prevents the occupants being crushed.



John Houghton

Car stopping distances are increased greatly by bad driving conditions – if the road is wet, icy or covered in leaves – or by poor brakes or tyres.

tion of safety glass. Recent research estimates that 11 lives per day in the United States alone are saved by fastened seat belts.

Even slight slackness in a seat belt will increase the chance of serious injury. Mechanical tensioners are therefore fitted to most seat belts, to take in any slack.

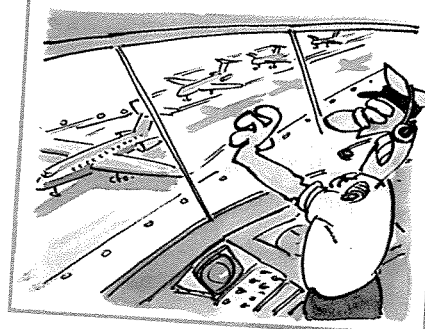
Hold tight

The tensioners store energy in a torsion spring and release it by a toggle mechanism on impact. Acting on both waist and shoulder sections at once, the device tightens immediately (within ten

Just amazing!

QUICK TAKE OFF

IN 1988 CHICAGO INTERNATIONAL AIRPORT HANDLED 795,026 PLANE MOVEMENTS: A LANDING OR TAKE OFF EVERY 40 SECONDS.



Paul Raymond



DEADLY COCKTAIL

Metropolitan Police



Alcohol is the single biggest factor in all road deaths and injuries. The legal alcohol limit per 100 ml blood permitted for drivers varies in different countries:

- India 0 mg
- Poland 20 mg
- Norway 50 mg
- Japan 50 mg
- UK 80 mg
- Eire 100 mg
- USA 100-150 mg
- Italy 80 mg

Alcohol is a 'depressant' drug that damps down the higher parts of the brain dealing with intelligent thought and judgement. It also seriously impairs co-ordination and reaction time.

It takes the adult body an average of one hour to get rid of the alcohol in one half pint of beer or one glass of wine.

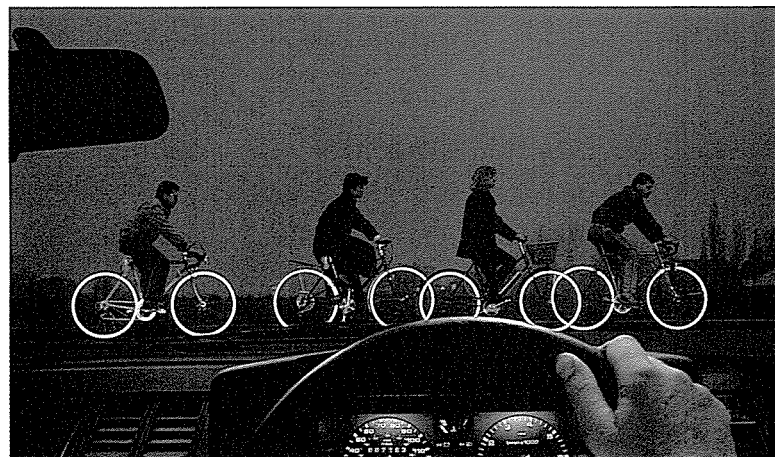
thousandths of a second) — before the occupant is thrown more than 5 mm forward.

During a collision, the driver is especially vulnerable since the steering wheel may be rammed into

his chest. For this reason, most new cars are equipped with steering columns that collapse if a sudden large force is applied to them.

The innovative steering wheel airbag reduces the risk of injury still further. The airbag is activated by an electronic trigger unit — which also activates the seat-belt tensioners — when a severe head-on collision is detected. A gas generator inflates the bag with pressurized

Reflective bicycle
tyres are a recent innovation to make cyclists more visible at night. Thousands of tiny glass reflectors — as used in police jackets — are bonded to the tyre wall and are clearly illuminated in vehicle headlights.



gas in a fraction of a second to protect the head of the driver.

The front seats may be fitted with high head-restraints so that if the car is struck from behind, the front-seat passenger and driver are less likely to suffer 'whiplash'. This happens if the head is forced back suddenly while the upper part of the spine remains rigid.

Air safety

With such a huge amount of space to fly in, it might seem that aircraft are fairly safe from the risk of

collision. But the sky is getting increasingly congested. Furthermore, because of the high cruising speed of jet airliners it may be too late for a pilot to react by the time he sees an oncoming plane.

Radar alert

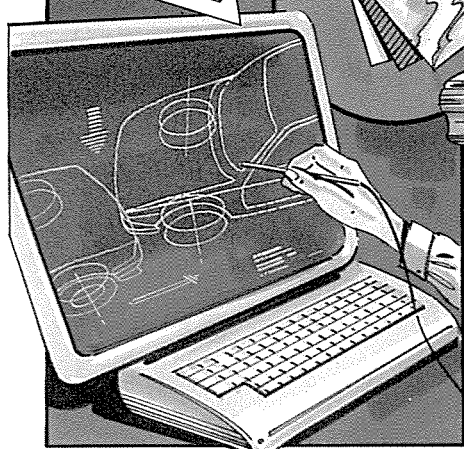
Two Boeing 747's, for example, flying directly toward one another, would close at the rate of about 320 metres per second.

To help avoid serious accidents, all aircraft must follow strict rules and procedures — especially near busy airports. Air-traffic controllers carefully monitor a plane's progress by radar. Commercial aircraft are now being fitted with a computerized radar, known as the Traffic Alert and Collision Avoidance System (TCAS). Two planes equipped with TCAS can exchange radio signals that give the aircrafts' position, course and speed. On-board computers then warn if the planes are too close to each other.

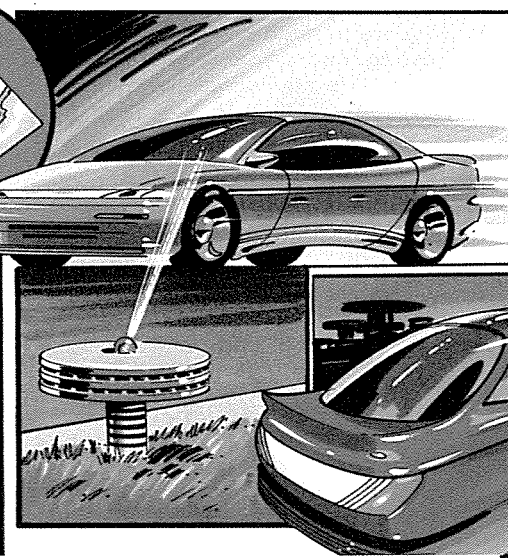
3M United Kingdom plc

INTO THE FUTURE

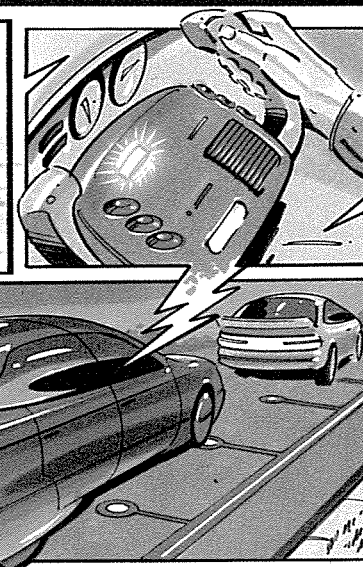
COMPUTER CONTROL



▲ Computers will simulate crashes to pinpoint a car's weaknesses and the car will be strengthened accordingly. New materials will give greater strength.



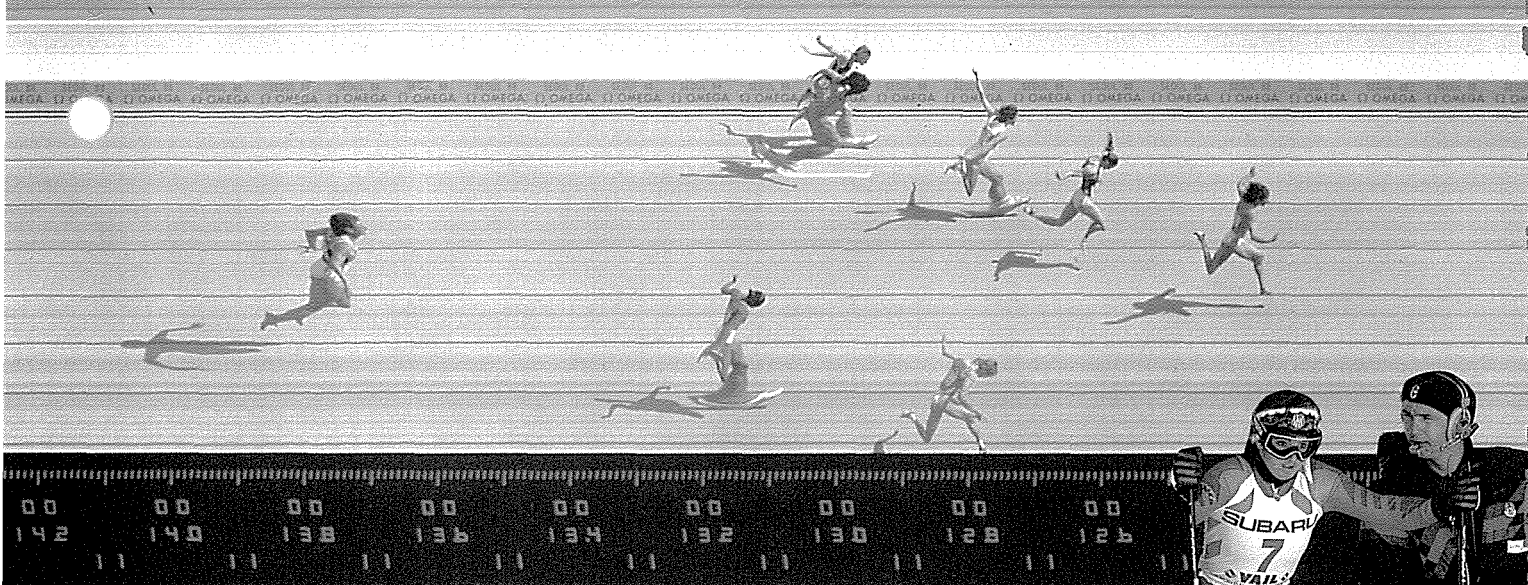
▲ Roadside computers working together with on-board microprocessors will warn when a vehicle is going too fast, and slow it down automatically.



▲ An electro-magnetic inductive loop system in the road will be able to detect when cars are travelling too close together and warn the drivers.

Joe Lawrence





GOOD TIMING

WE LIVE IN A UNIVERSE FULL of motion — moving people, cars, aircraft, satellites and even entire galaxies. The accurate measurement of speed, or of the time taken to do something, is often vital, whether to decide if a new track record has been set or to show a pilot if his speed is exactly right for take off.

The type of equipment used to measure speed depends very much on the application and the level of precision it demands. A stopwatch, for instance, may be able to display times to the nearest hun-

dredth of a second, but is only as accurate as the person who operates it. Any method of timing that depends on human judgement and reactions will be uncertain by at least a few tenths of a second — not sufficiently accurate for professional sport.

Speed measurement

In drag racing — a contest in acceleration over a quarter-mile course from a standing start — the two cars involved start the race clocks automatically when their front wheels break beams of light shining on photoelectric cells. A few seconds



Ready to go. Tamara McKinney (USA) triggers a timing device as she begins a downhill ski race. A new Olympic record is set by Jondanka Donkova (Bulgaria) completing the 100 metres hurdles in 12.38 sec (top).

Duomo/Coloursport

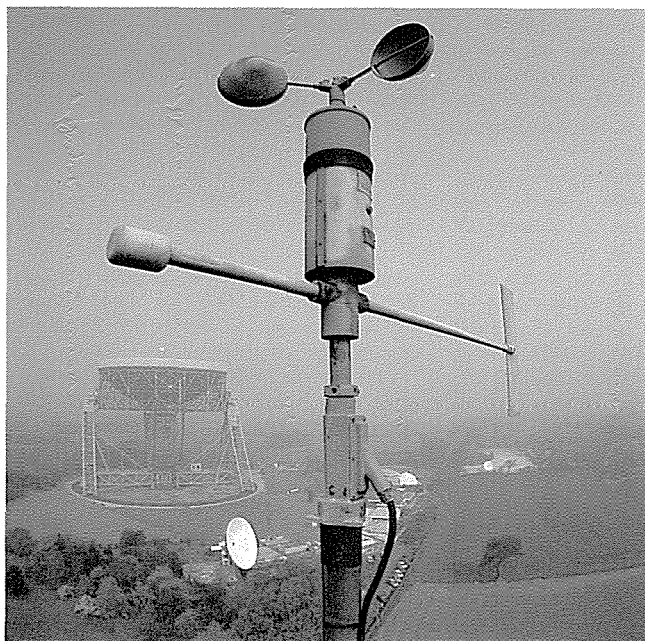
later, when the competitors cross the finishing line, interrupting a second light beam, the clocks are stopped.

A similar system is used in top-class athletics. In this case, a timing computer, accurate to one thousandth of a second, is sent an electrical signal from the starter's pistol when the trigger is pulled. As each runner crosses the finishing line, two parallel infra-red beams are broken and the computer receives another signal to record the elapsed time for that competitor.

Progress monitor

The timing mechanism of a downhill ski race is set off when the skier opens the start gate. Photoelectric cells, activated as the skier passes through light beams, record the times at various points down the course, and at the finish. The whole system is linked to the scoreboard and the television control room so that as the race is taking place, viewers can compare current times,

An anemometer is an instrument used to measure wind speed. The concave (inward curving) surfaces of the cups offer greater resistance to the wind than their convex (rounded) surfaces, causing the cups to rotate. In steady wind conditions the cups rotate at a speed approaching that of the wind. Its speed is calculated by measuring the rate of rotation of the shaft.



David Parker/Science Photo Library



accurate to within a millisecond, with those of the competition leader.

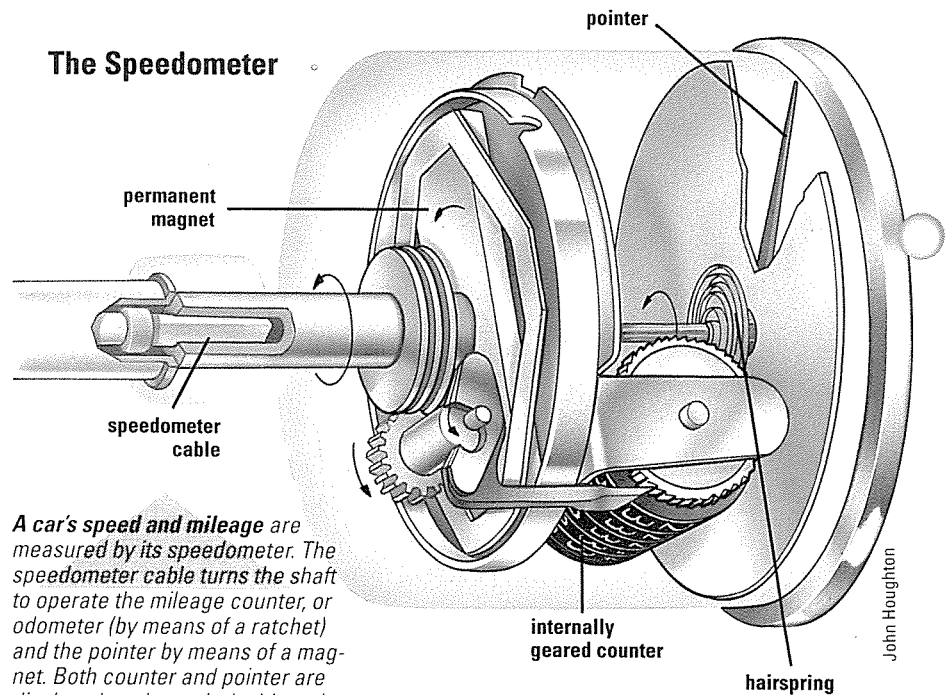
The speed of most cars, trucks and other vehicles is shown by a speedometer. As the vehicle moves along, a flexible cable, connected to the drive shaft, spins a magnet around. This sets up a magnetic field around an aluminium ring surrounding the magnet. The interaction of the two magnetic fields causes the ring to rotate as well.

Road speed

Since the aluminium ring is joined to a spring it can only turn so far – the amount by which it twists being shown by an attached needle against a calibrated scale on the driver's control panel. Similar equipment measures the speed of ships, but in this case the flexible cable leads to a rotator towed along under the water.

Increasingly, these mechanical

The Speedometer



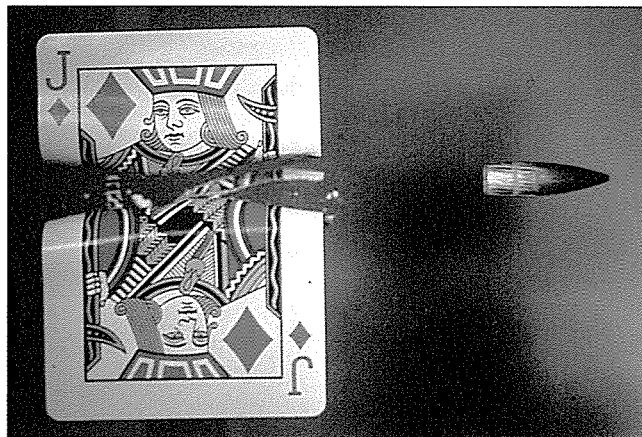
A car's speed and mileage are measured by its speedometer. The speedometer cable turns the shaft to operate the mileage counter, or odometer (by means of a ratchet) and the pointer by means of a magnet. Both counter and pointer are displayed on the car's dashboard.

Ripping apart a playing card, a .30 calibre bullet is 'frozen in time' by an exposure duration of less than 2 millionths of a second.

Microprocessor technology allows holographic dashboard displays in this prototype car to show speed, journey time and fuel consumption.

The speed of natural objects in Space can be calculated using the Doppler principle, which describes the law of the change in wavelength when a source of vibrations is moving towards or away from the observer. This works with all types of waves including sound.

If a star is moving towards Earth,



Professor Harold Edgerton/SPL

devices are being replaced by sophisticated electronic systems. In many new cars on-board computers and digital displays play a key part. An instrument computer receives messages from various electronic sensors that allow not only the current

speed, but other data, such as average journey speed and estimated time of arrival, to be flashed up on request.

Air speed

A knowledge of how fast his plane is travelling is especially crucial to an aircraft pilot. For each type of plane, there is a narrow range of safe speeds for taking-off, cruising and landing, according to its load. If the speed drops too low, for example, there is a serious risk of stalling.

An instrument called a pitot head measures the aircraft's speed. This has two tubes, one of which is open to the direction of flight so that air is forced down it as the plane moves forward. The second tube has openings along the side only which allows the surrounding air pressure to be measured. Both tubes lead inside the aircraft to a sealed container which holds a thin metal capsule connected to a pointer on a dial. The difference in pressure between the air in the two tubes which depends on the aircraft's speed cause the capsule to expand or contract – movements which are transmitted to the airspeed indicator in the cockpit.



George Haling/SPL

more light waves are received from it in a given time than if it were stationary. In other words the wavelength of its light appears shorter – its light appears bluer. The characteristic dark lines in the star's spectrum are shifted towards the blue end of the spectrum 'blue shift'. The opposite effect occurs when a star is moving away from Earth. Fewer light waves are received in a given time. The wavelength appears longer; the light appears redder. The spectral lines are shifted towards the red end of the spectrum 'red shift'.

The light from remote galaxies shows significant red shifts, indicating that they are all moving away from us and from one another. This provides evidence that the Universe is expanding. Using the Doppler principle, scientists have worked out that the expansion began about 15 billion years ago, when a cataclysmic explosion they call the Big Bang created the Universe.

Just amazing!

FRACTIONAL EXPOSURE
A TYPE OF CAMERA CALLED AN IMAGE CONVERTER CAN TAKE EXPOSURES LASTING ONLY ONE-MILLION-MILLIONTH OF A SECOND!



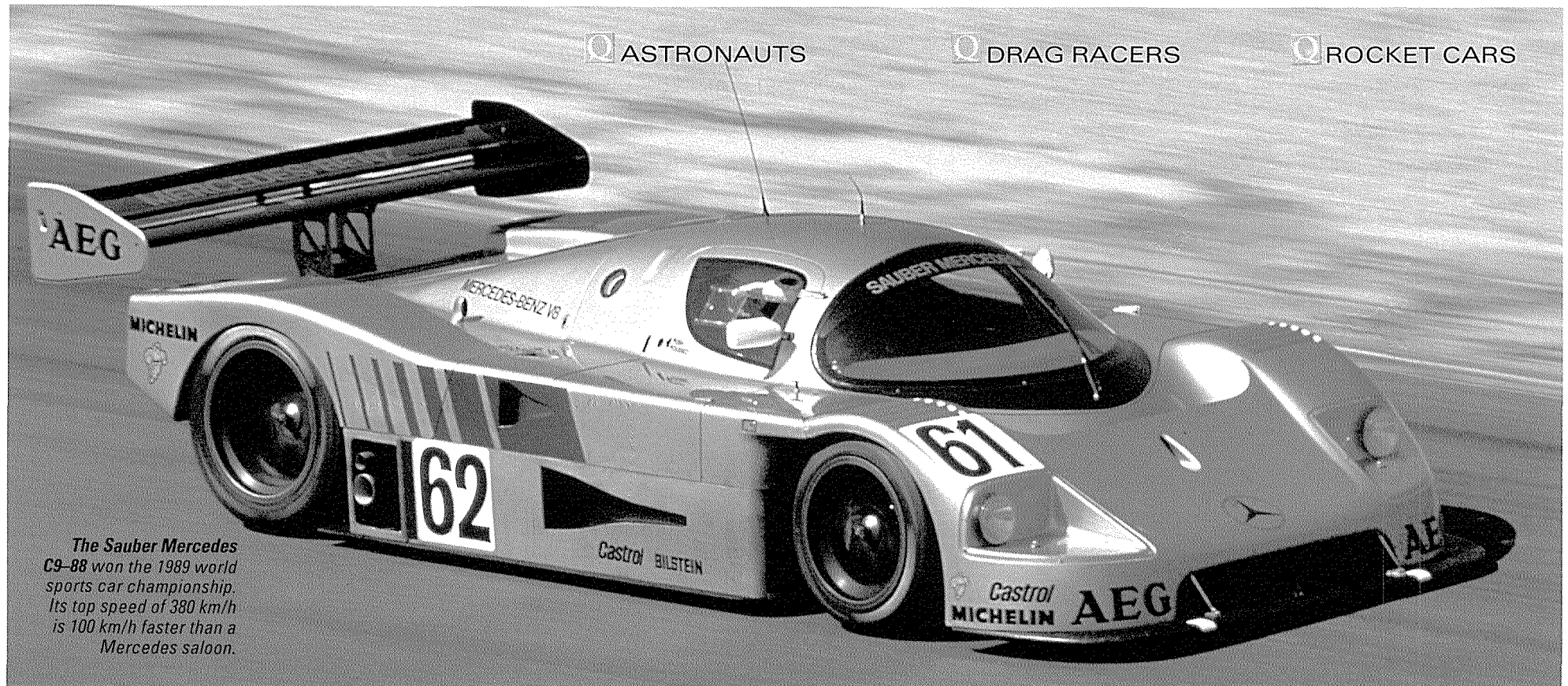
Paul Raymond



Q ASTRONAUTS

Q DRAG RACERS

Q ROCKET CARS



The Sauber Mercedes C9-88 won the 1989 world sports car championship. Its top speed of 380 km/h is 100 km/h faster than a Mercedes saloon.

Colorsport

MEAN MACHINES

SINCE THE DAWN OF TIME, Man has pushed himself to the limit in an effort to travel faster than ever before. On land, on water and in the air, speed records have been broken, often in vehicles far removed from normal forms of transport.

Astronauts can lay claim to being the ultimate speedsters. Even to go into Earth orbit, they must accelerate to about 28,000 km/h. On journeys to and from the Moon, the crews of the US Apollo missions reached still greater speeds. Commander Eugene Cernan, Comman-

der John Young, and Colonel Thomas Stafford officially became the fastest humans of all time when their Apollo 10 capsule surpassed 39,897 km/h during re-entry on 26 May 1969.

Speed on Earth

In Space there is nothing to slow or hinder an object moving at high speed. On Earth, however, the situation is very different. Gravity, air resistance and friction with the ground or with water all tend to work against record-breaking attempts.



Speed (km/h)	Method (& name)
43.3	Running (Carl Lewis, 1988)
69.6	Horse riding ('Big Racket', 1945)
245	Bicycle (John Howard, 1985)
223.7	Ski-ing (Michael Prufer, 1988)
346	Boat (propeller-driven)
405	Passenger train (experimental, 1988)
512.7	Motorcycle (Don Vesco, 1978)
556	Boat (jet-engined - 'Spirit of Australia', 1977)
690.9	Car (wheel-driven - 'Bluebird', 1964)
1,019.4	Car (jet-engined - 'Thrust II', 1983)
2,333	Airliner (Concorde, 1988)
3,529.5	Jet plane (SR 71A 'Blackbird', 1976)
6,121	Unmanned train (rocket sled, 1982)
39,897	Space capsule (re-entry of Apollo X, 1969)

Every time you ride down the motorway you travel faster than anyone had done by road before the turn of this century. Dramatic improvements have been made to the engine, transmission, suspension and body of cars over the last few decades. These have resulted in equally spectacular progress in the performance of road vehicles.

Exotic production sports cars like the Lamborghini Countach, Ferrari F40 and Aston Martin V8, for example, are now capable of going from 0 to 100 km/h in only about 5 seconds, with a top speed of up to 290 km/h. A Formula 1 racing car can accelerate even harder and reach about 340 km/h.

In drag racing, specially-adapted cars called dragsters compete in pairs on a straight 402-metre track. The fastest are the 'top fuellers' –

with the ground. To further increase traction, drivers purposely spin their rear wheels in water or a special chemical before the start of a race to make the surface of the tyres sticky.

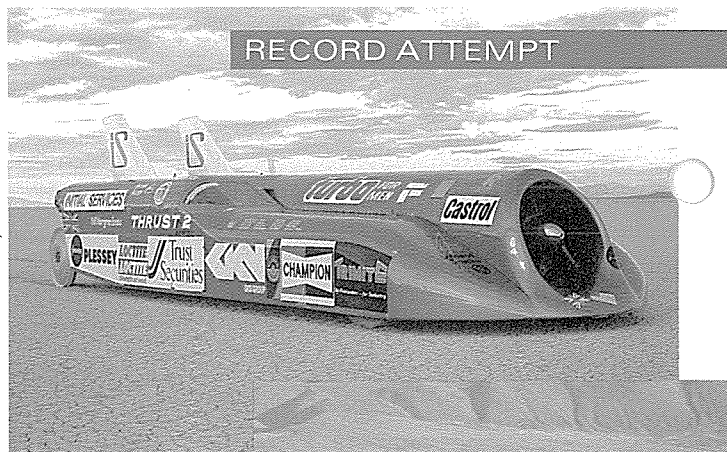
Top drag racers can complete the 402-metre run in less than 5 seconds from a standing start. They can reach a final speed, or terminal velocity, in excess of 470 km/h. An unofficial record of 476.43 km/h was set by Gary Ormsby (USA) in 1990.

Land speed records

Even the speeds of top drag racers, though, are puny compared to those achieved in modern attempts on the world land speed record. On 4 October 1983, British driver Richard Noble reached the highest official land speed ever of 1,019

RECORD ATTEMPT

The National Motor Museum, Beaulieu



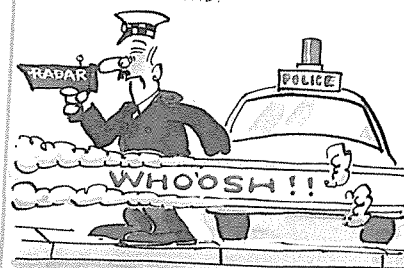
When Richard Noble broke the official land speed record in Thrust II (top) in 1983, he had to adhere to strict rules. The car must make two timed runs over 1 mile in opposite directions – to cancel out any effects of wind – with no more than an hour between runs. The driver accelerates to maximum speed before the start of the measured distance and so gets a flying start. His officially recorded speed is then the average of the two one-mile runs. Only very wide stretches of perfectly flat, dry land, such as the mudflats and saltbeds of desert regions in the United States and Australia are suitable for record attempts. Thrust II reached 1,019 km/h in Black Rock Desert, Nevada.

Drag racing can be a dangerous sport. The engines run on a potentially explosive mixture of nitromethane and methanol.

Just amazing!

ROCKET MAN

AMERICAN STAN BARRET IS THE FASTEST MAN ON WHEELS HAVING DRIVEN HIS 3-WHEELED, ROCKET-ENGINED CAR AT AN UNOFFICIALLY RECORDED 1,190.377 KM/H – JUST OVER THE SPEED OF SOUND.



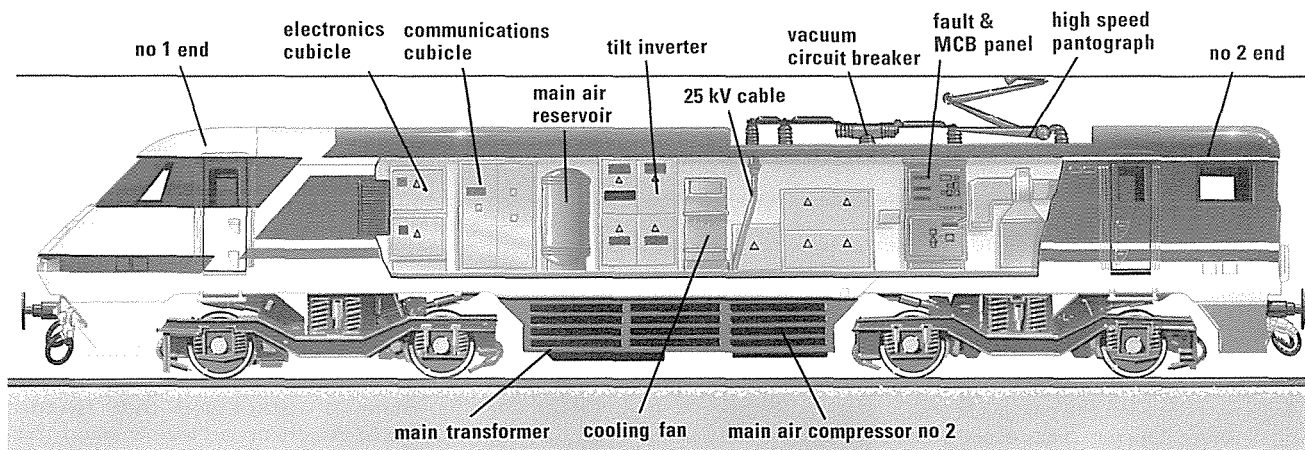
Paul Raymond

low slung, rear-engined racers that run on a highly volatile mixture of methanol and nitromethane fuel in supercharged engines that makes them more powerful than any other type of racing car.

Since the bulk of a dragster's weight is at the back, huge rear tyres are fitted in order to gain maximum grip on the road. Known as racing slicks, the tyres are completely smooth and the outer casing is kept at a low pressure so that a large area of rubber is in contact

km/h over the Black Rock Desert in Nevada. His car, Thrust II, was powered by a Rolls Royce Avon 302 jet engine taken from a Lightning fighter plane.

One of the main problems was to prevent Thrust II from becoming airborne. This was achieved by giving it a long, low body and a shape that caused the car to be pressed down as it travelled at high speed. Because rubber-tyred wheels would have melted, aluminium ones were used instead.



David Gibbons/GEC Alsthom/Joel Lawrence



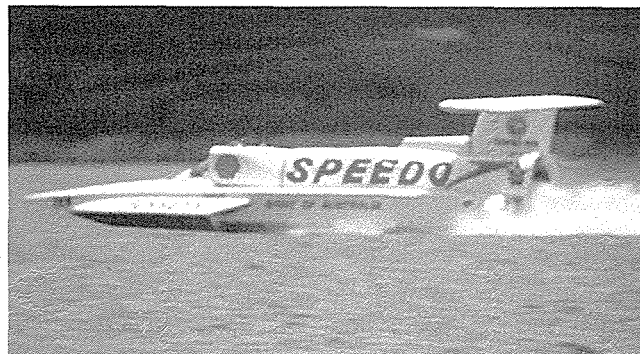
The Inter-City 225 is British Rail's high-speed train. It uses on-board computers to link the four electric motors, which can propel the train to speeds of more than 225 km/h.

ory is much lower, at 346 km/h.

Among sailing boats, the highest speeds are often achieved by multi-hulls — catamarans and trimarans — though this largely depends on conditions. In some contests, like the America's Cup, there are rules governing, for example, the size of the hull and the height of the various sails. This means that, in trying to

The dangers and difficulties facing record-breaking attempts are even greater on water. Apart from offering more resistance to an object moving through it, water is unpredictable. A slight breeze, for instance, can generate waves large enough to be a threat to a high-speed boat.

Speeding through the water, Ken Warby set a new world record in 1977 with Spirit of Australia, a jet-powered hydroplane.



Topham Picture Library

Bluebird tragedy

In 1967, Britain's Donald Campbell met his death during the second run of his record-breaking attempt across Lake Coniston when his turbine-powered Bluebird collided with the wake from his previous run. The buffeting was enough to cause Bluebird to lift, somersault through the air and crash back into

the lake before sinking. When the accident happened, Campbell was moving at a speed of 527 km/h.

Currently, the official water speed record stands at 514 km/h, clocked by Australia's Ken Warby in 1978 in a jet-powered hydroplane named *Spirit of Australia*. Propeller-driven boats cannot achieve this much thrust, so the record for this category

come up with a faster vessel, designers must work within strict guidelines (see 'COMPUTER-AIDED DESIGN', page 188).

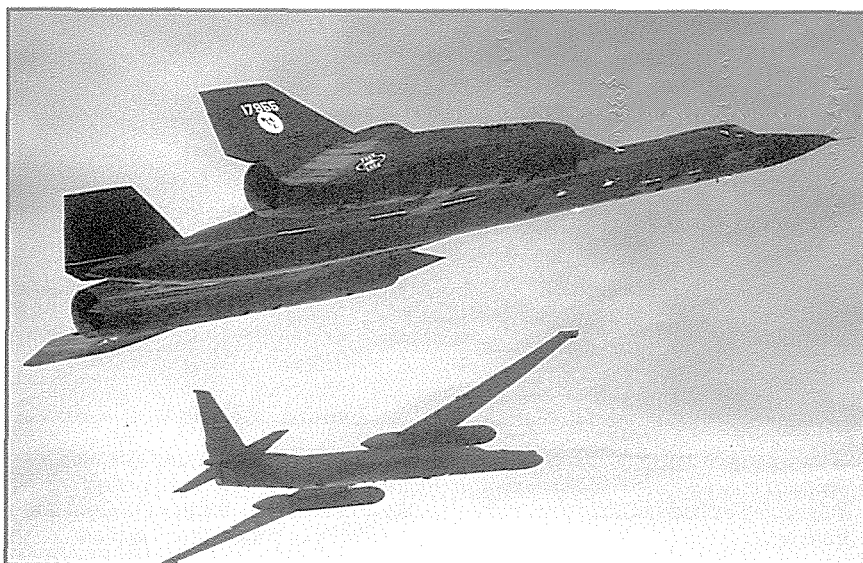
In the air

Streamlining and high motive power are two chief factors in breaking speed records on land and water. These same factors are also crucial in achieving high speed in the air. But here there is another consideration. Planes that travel at several times the speed of sound generate so much friction with the air that their leading edges must be protected from melting. While the rest of the aircraft may be made of lightweight aluminium or titanium alloy, the nose-tip and leading wing edges are coated with a heat-resistant material like stainless steel.

Fastest of all airliners by a long way is Concorde, which is capable of 2,333 km/h, or 2.2 times the

Blackbird in flight. The US Lockheed SR-71A spyplane (top) is officially the world's fastest aircraft. It reached a speed of 3,529.5 km/h over a 25 km course in California in 1976.

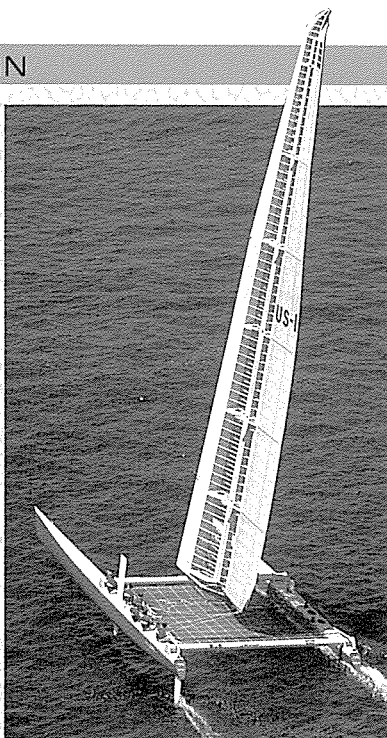
Gamma/Frank Spooner Pictures



COMPUTER-AIDED DESIGN

In 1983, a United States yacht lost the America's Cup for the first time in over a century of competition. The trophy went to *Australia II*, a yacht featuring a revolutionary new keel with a wing-like structure at its base. An American team quickly set about designing an even faster boat to help regain the cup for the United States four years later.

Central to the design team's efforts was a computer that ran programmes modelling the behaviour of different-shaped hulls, keels and sails under a wide range of wind and sea conditions. Each computer run cost about £10, compared to about £25,000 to build and test a model in a tank, and about £500,000 to construct a full-scale yacht. Because of this, hundreds of different ideas could be tried before the team settled on a final design. The result was *Stars & Stripes*, which won the America's Cup in 1987.



Bob Griener/Allsport

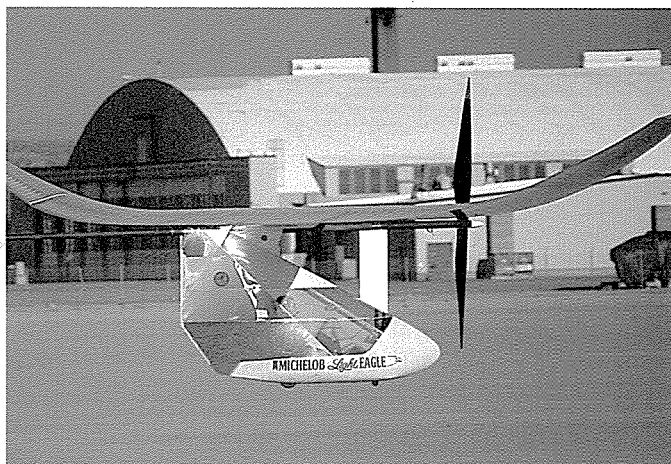
speed of sound. But some military and experimental aircraft have flown much faster. The American SR-71 Blackbird spyplane, for example, can cruise at Mach 3, which is three times the speed of sound. This plane set the fastest ever speed for an aircraft when it reached 3,529.5 km/h in 1975 over Beale Air Force Base in California. Russia's MiG-25 fighter - code-named 'Foxbat' - has been tracked by radar at about Mach 3.2 or 3,395 km/h.

Because of the need to keep air resistance down, the faster a plane goes, the higher it tends to fly. The

Daedalus 88, a pedal-driven plane, holds the record for human-powered flight. With Greek cycling champion

Kanellos Kanellopoulos at the controls, it flew 120 km between the islands of Santorini and Crete, before crashing into the sea 9 metres short of the landing area.

The flight lasted nearly 4 hrs, averaging 27.7 km/h.



Gamma/Frank Spooner Pictures

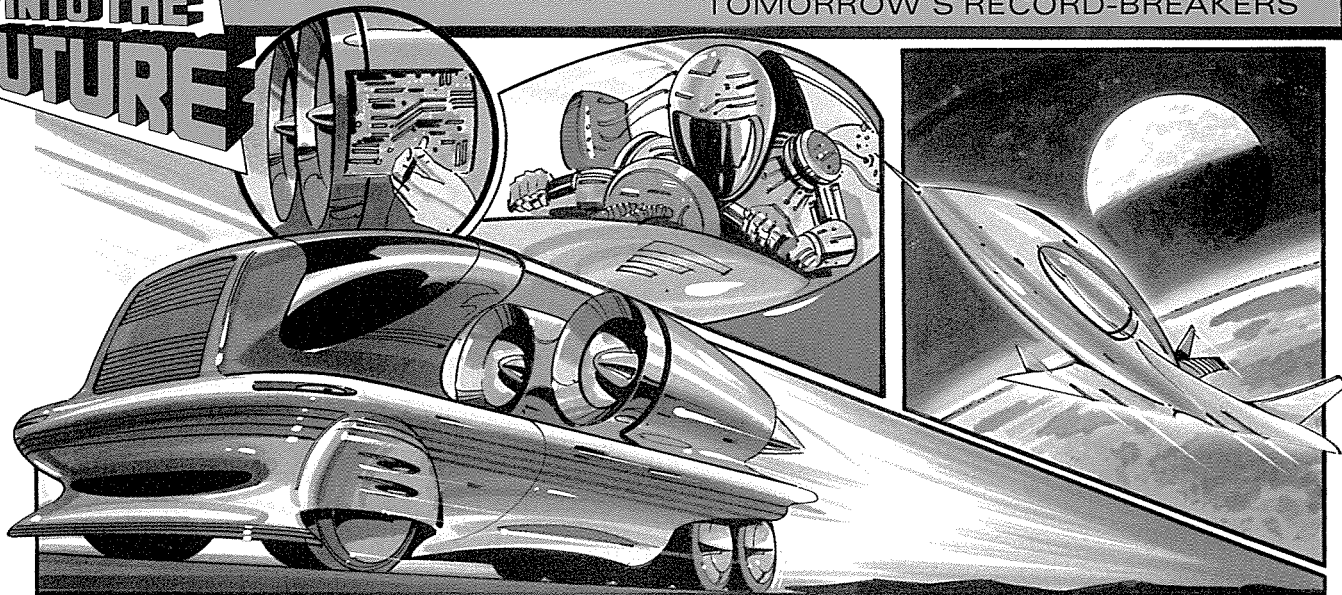
SR-71, for example, cruises at an altitude three times greater than that normally reached by commercial airliners. In the late 1960s, the US North American Aviation X-15A-2 flew at heights up to 108 km. Powered by a rocket engine, burning a mixture of liquid oxygen and ammonia, it was also the fastest fixed-wing aircraft in history, reaching a top speed of 7,297 km/h.

Fastest trains

Rocket-power was also behind the fastest-ever railed vehicle, an unmanned rocket-sled that reached 9,851 km/h on a New Mexico missile range in 1982. But the fastest train with passengers aboard was a West German Intercity experimental train, which reached 406.9 km/h on a test run in 1988. Then, in 1990, a French TGV train broke the record by clocking up 515 km/h. France has overtaken Japan in the construction of special railways that can accommodate ultra-fast trains.

INTO THE FUTURE

TOMORROW'S RECORD-BREAKERS



▲ Today's high-speed records may be smashed in the future by using cars with computer-controlled rocket engines and light-weight construction materials.

▲ For the sake of safety, robots or androids may take the place of human drivers and pilots in pushing back the frontiers of speed.

▲ Hypersonic airliners and spaceplanes could set up a new category of record - the fastest flights between the Earth and the Moon, or even different planets.



SIMULATORS ■ SOFTWARE ■ VIRTUAL REALITY

WONDER WORLDS

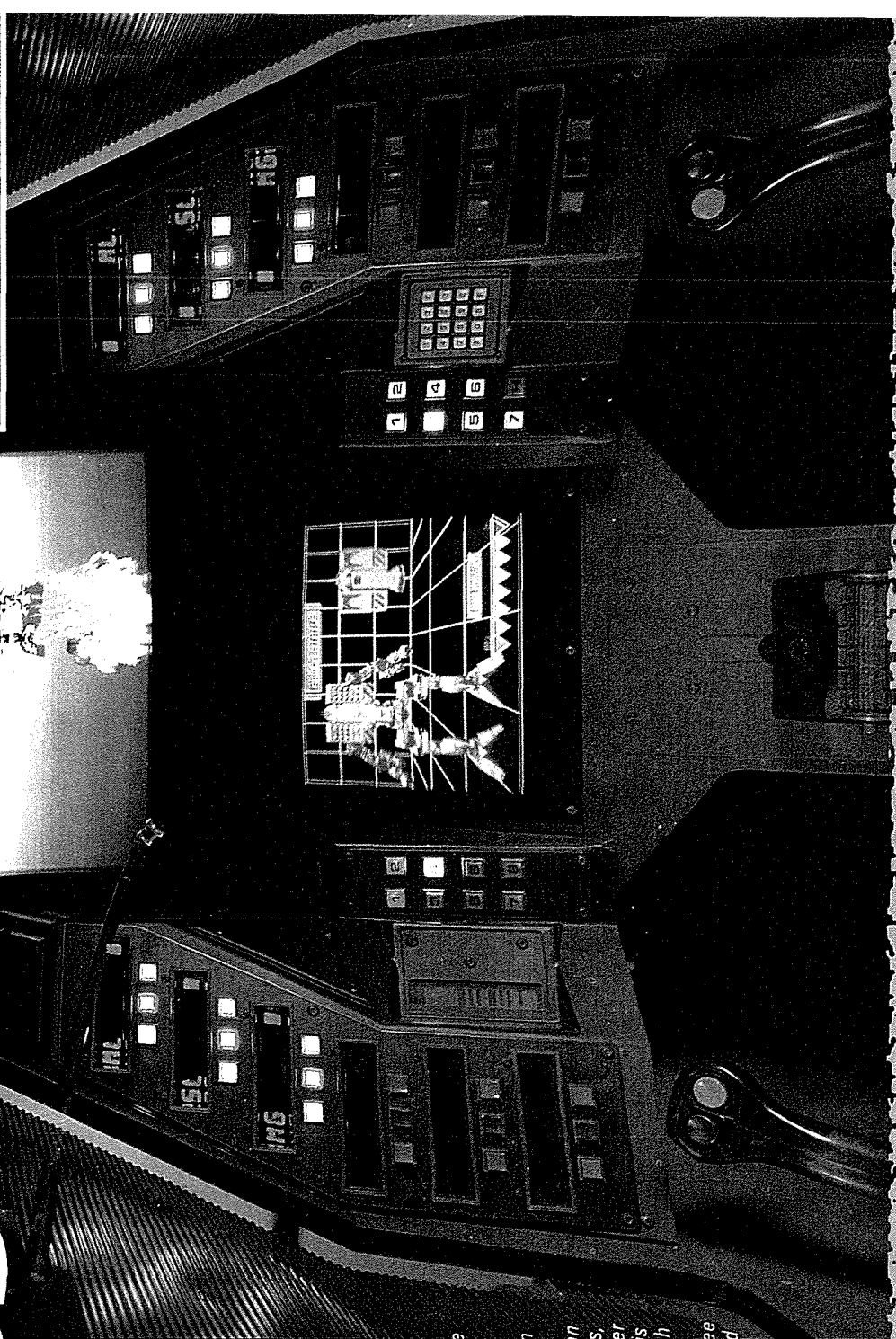
PILOTING SPACE PROBES TO Mars, driving Formula 1 cars around Grand Prix circuits, or facing life or death struggles against inhuman monsters – today's computer games are capable of providing a totally new world of wonder and entertainment.

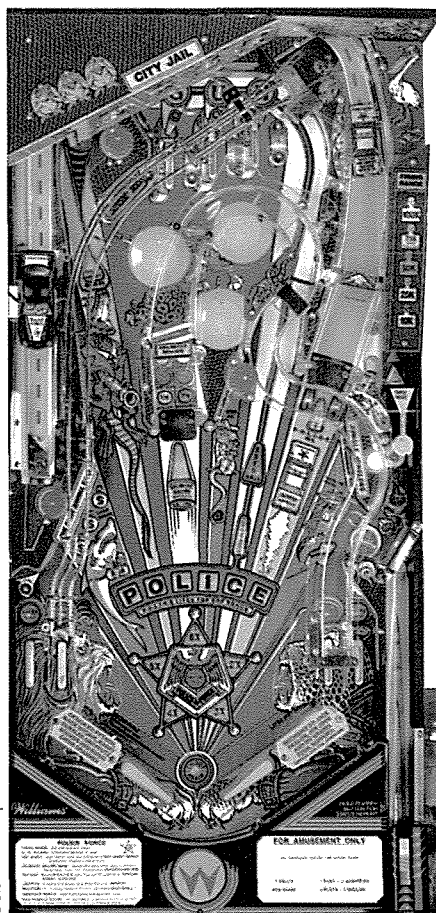
Electronic games, in arcades and at home, have come a long way in the last ten years. In the early days, the graphics and sound effects were frequently both clumsy and unconvincing. Now, though, thanks to some remarkable advances in computer technology, pictures and accompanying sounds of stunning quality can be produced. In the best games, the player becomes totally involved in an imaginary electronic world that he can control with a wide variety of switches, pedals, joysticks or keypads.

Fast response

At the heart of every electronic game is a computer running a program. In a coin-operated arcade machine, or 'coin-op', the computer usually contains a number of special-purpose chips. At the factory, these chips have the game's program installed into

Mechwarrior, the latest US arcade game, is unique among simulation games in that players embark on missions in teams, with each member in command of his own vehicle. Each cockpit is controlled by three computers, linked via a local area network to the others.





Pinball games, under the control of microprocessors, are far from dead. Arcades offer a wide variety of different scenarios.



ZEFA

handle much larger memories and to process information a great deal faster than previously possible.

Software

Instead of the primitive, 'chunky' graphics of 8-bit micros, the latest 16-bit machines can generate realistic, moving pictures with a fantastic range of colours and textures. At the same time, the scope for computer games has never been wider or more promising.

A huge choice of recreational computer software is now available. But, basically, most computer games fall into three main categories.

First, there are arcade action games, in which a common goal is to shoot down as many of the enemy as you can before they shoot you. This makes them ideal for use in amusement arcades since they demand little or no experience and usually end quite quickly. To keep skilled players interested, however,

several levels are programmed in, each one harder than the one before. Hundreds of such games have been developed for video arcade machines and home computers, and even in tiny, hand-held versions fitted with LCDs (or liquid crystal displays).

Make believe

A totally different kind of challenge is offered by computer adventure games. Here the object is to find a way through an imaginary world, such as an underground maze of tunnels and caves. In the computer's memory are stored the details of each location in the maze so that this can be shown on the screen as a colourful picture. The computer also keeps track of the adventurer's possessions, weapons, and state of health, as well as the whereabouts of any creatures that may be lurking within its make-believe world.

An interesting feature of adventure games is their use of simple artificial intelligence to understand and communicate with the person playing. The computer has to be able to scan a short sentence given to it, extract the meaning, then act accordingly.

Laser disc

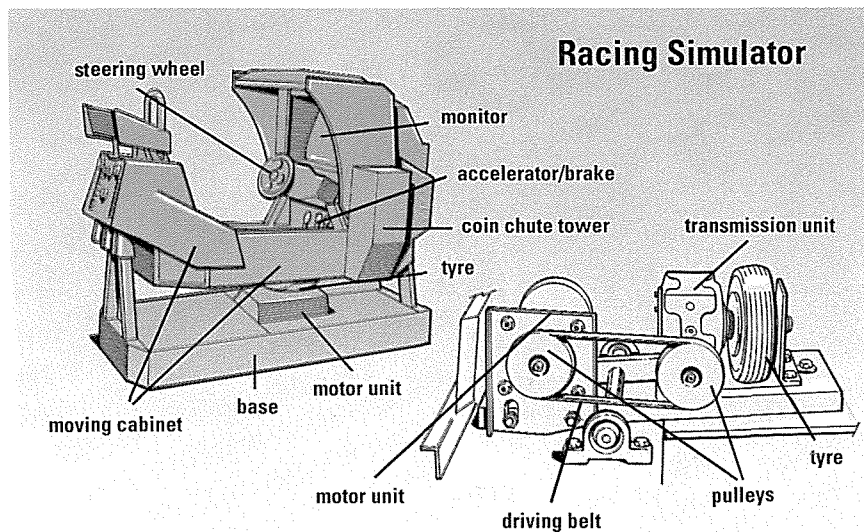
An adventure may take many hours, or even days, to complete. When faced with a particular problem, the player often has to stop and think before being able to move on. For this reason, few adventure games have found their way into amusement arcades.

One notable exception is *Dragon's*

them. The result is a game that can be played at very high speed and that responds instantly to the control sticks or pedals.

By contrast, the chips inside a personal computer are general-purpose. In other words, they can be loaded with many different games programs, as well as other types of software, although they may not work quite as fast as a 'coin-op'.

Today, most new microcomputers are built around chips that work with 16 bits, or binary digits (ones and zeros), of data at a time, instead of just 8 bits. This allows them to



Joe Lawrence

Arcade games can be made more enticing if player participation is increased. One way of achieving this is with a light gun, which can fire at on-screen targets.

Simulator games feature a moving cabinet, driven by a microprocessor-controlled motor, which turns a tyre against the base of the freely swivelling cabinet in which the player sits.

Lair, a spectacular arcade game in which moving cartoon pictures and sounds are stored on a laser disc. At various stages in the adventure, the player has to make snap decisions and sometimes fight a monster on the screen using the controls provided. Depending on what the player does, the computer jumps to one of several new points on the

laser disc where the story is continued and combat resumed.

Simulations are a third category of computer game, in which the object is usually to fly an imaginary aircraft. On the screen, the plane's dials and instruments are shown, together with the view through the front window.

Aerial dogfight

As the player-pilot operates the controls, the computer works out the effect this would have on the aircraft from one instant to the next. The more elaborate simulations let the player choose from a range of different aircraft, weather conditions, and airports around the world.

Not only are the graphics and sounds of electronic games becoming more realistic. Some of the latest arcade machines incorporate a powered chair that throws the rider around as if in an aerial dogfight or 'Star Wars' shoot-out. The British company, Konix, now even offers such a chair linked to a screen and games console for use in the home.

A further variant of the simulator game is the 'games centre'. Pioneered by the ESP Corporation of Chicago, US, these centres feature simulators that are linked by both radio and computer so that the games can be played in teams. Players pay for a half-hour game that includes training and strategy sessions and ten minutes of actual play.

Every game involves a different mission and assortment of combat

vehicles. Even the terrain and time of day changes — it may be daylight, dusk, or night. And because humans make the decisions, the possibilities are endless.

Controlling each cockpit are three powerful computers, linked via a local area network to the computers inside the seven other cockpits. A massive, 32 million-character memory holds 19,000 graphic images that can be called up and manipulated by the battle simulator. The

result is that each player sees, from his own perspective, a realistic, ever-changing view of the action taking place.

Eye-Phone

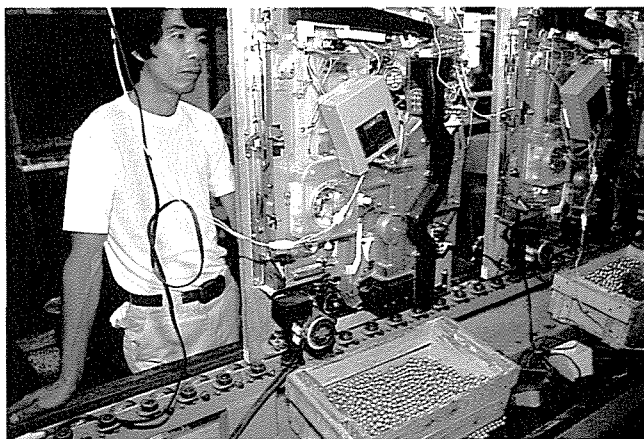
The first of these games was Mech-Warrior and the so-called 'BattleMech' cockpits simulate land-based vehicles. Future versions, however, may let players fly in anti-gravity tanks or dive in mini-sub to search for a sunken ship.

ONE-ARMED BANDITS — NO-WIN GAMBLING



Assembly line in a Japanese factory, making the highly popular arcade game called pachinko, played with small balls.

However skilful a player thinks he is, a fruit machine can never be beaten. Not even luck can help because the machines are controlled by special computer programmes to pay out about 70-80 per cent of the money fed in. This figure has been calculated, through experiments with people and apes, to provide maximum addiction. The revolving reels do not spin due to momentum but are attached to stepper motors that move as instructed by the on-board computer. When the reels stop just one position short of a win they are simply obeying a computer command given before the player even started them spinning.



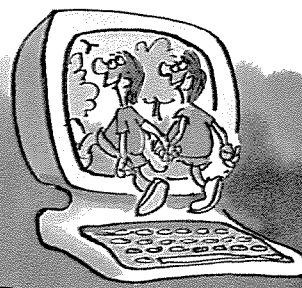
Gamma/Frank Spooner Pictures

Home computer games offer arcade quality sound and graphics with powerful, 16-bit (binary digits) microprocessors. Games come on cartridge or disc, depending on the system. A joystick, often incorporating a fire button, offers rapid control.

Just amazing!

REAL FANTASY

IN 'REALITY BUILT FOR TWO' TWO PEOPLE CAN SHARE THE SAME VIRTUAL REALITY — WITHOUT LEAVING THEIR CHAIRS. THEY CAN SHAKE HANDS AND EVEN STROLL THROUGH THE COMPUTER'S SIMULATED WORLD.



Paul Raymonde



As with other arcade games, novelty is all-important and it takes just 20 minutes to reload the system with a fresh set of graphics and brand new software.

Power glove

A still more amazing effect is that created by 'virtual reality', where the user dons a special helmet and glove linked to a computer. The helmet, known as an Eye-Phone, shuts out the real world and replaces it with a computer-generated landscape displayed on a miniature TV screen. As the wearer moves his head, sensors in the Eye-Phone detect this movement and cause the computer to sweep to a different part of the imaginary scene. Similar sensors in the glove, called a Power glove, detect the slightest movements of the wearer's fingers. The result is that a person can actually pick up objects he sees in the computer-made world as if they were real.

In the future, 'virtual reality' may be extended to allow an unlimited number of people to take part, even

if they are located thousands of kilometres apart. Photographic-quality graphics, 'surround-sound', and devices like powered chairs will gradually make the computer's fantasy worlds seem amazingly real.

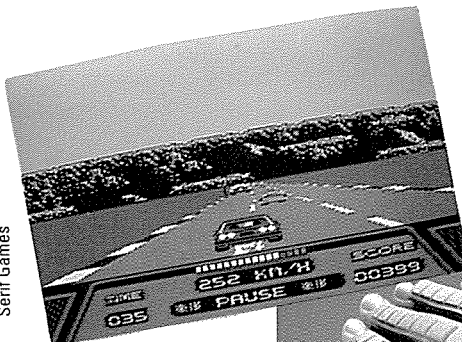
If 'virtual reality' is not real enough, then one can embark on a combat game. Primitive but hugely

popular throughout the world is 'paintball adventuring'. This is a team activity for groups between 10 and 100 people. The paintball adventurers are armed with air pistols, accurate up to 35 metres, that fire harmless, biodegradable paint pellets that wash away with water.

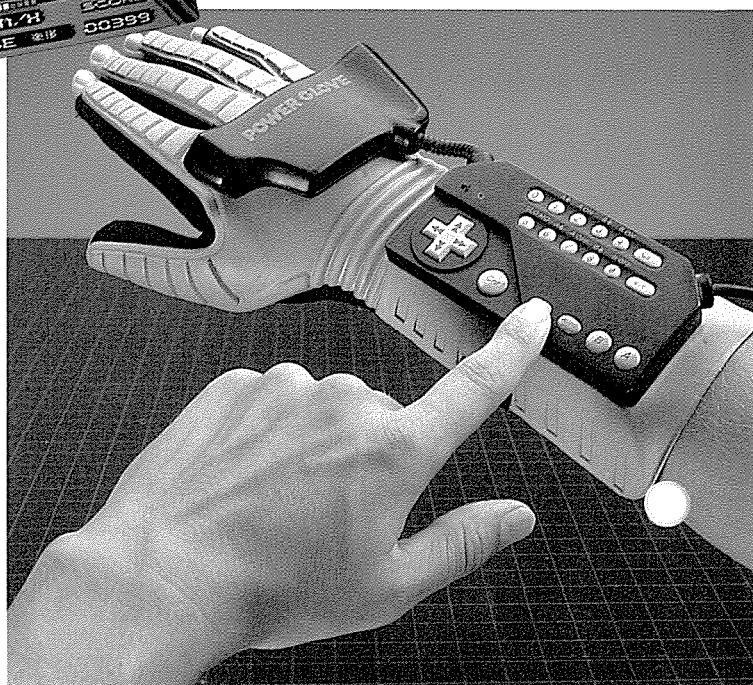
Painted out

Each player is provided with protective goggles, visor, headcovering and camouflage overalls and is 'eliminated' if hit by a paint pellet. The basic game involves two teams whose objective is to capture a flag from the enemy's camp and safely take it back to their own flag-camp.

Nintendo of America Inc.



The power glove plugs directly into the computer. Sensors in this programmable glove allow finger and hand movement to control objects and characters on the screen (above) and 'customize' games.



Photon Warrior is an electronic combat game in which two teams of players battle for supremacy in specially constructed rooms. Each player has a chest pod that records 'hits' from guns that emit an invisible, infrared beam.

INTO THE FUTURE



WORLD WAR GAMES



▲ Future games players will enter an enclosed game capsule in the home, equipped with 'sensurround' sound and high-definition, 360° graphics.

▲ Many players around the world, either individuals or team groups, will be able to take part in the same fantasy through global computer networking.

▲ 'Virtual reality' headsets will completely shut out the real world and replace it with a computer fantasy within which the players can pit their wits.

Joe Lawrence





-  ROLLER-COASTERS
-  SPINNING WALLS
-  SPACE TRIPS

TERROR RIDES

***The Shock Wave** in Dallas consists of two large loops following in tight sequence. The train reaches a height of 30 metres. Centrifugal force ensures passengers remain firmly planted in their seats even when travelling upside down (inset above).*

THE BEAST HURTTLES DOWN an almost sheer drop. Its victims, held securely in its grip, scream as they approach the final twist.

All new amusement park rides are designed with the help of computers and tested thoroughly as prototypes before anyone is allowed to step into them. Once in operation, technology ensures the ride runs smoothly, while providing the maximum number of thrills. Sensors indicate whether or not the safety bars are down and locked and a computer will operate the ride.



Ready to roll

All roller-coasters work in the same basic way. At the start of the ride, the cars are hauled up a long, steep incline by a continuously moving set of metal teeth. Having reached the top, the teeth disengage and the cars roll down the other side, rapidly gathering momentum. As they





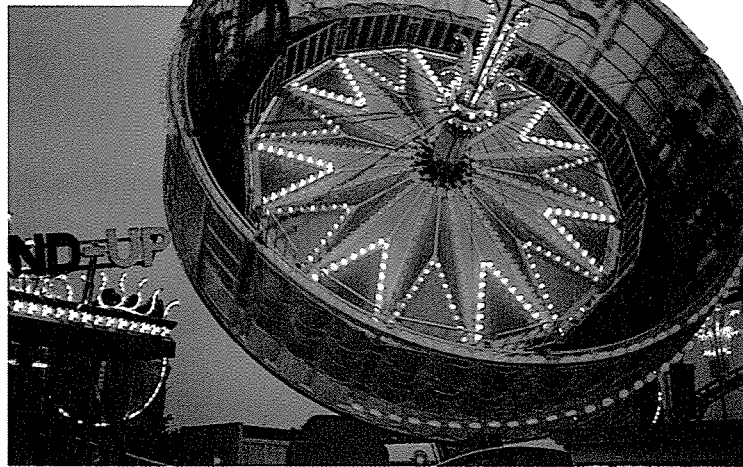
ROLLER HORROR

On a sunny afternoon in June 1987, 19-year-old Karen Brown and her fiancé climbed on to the Lightnin' Loops roller-coaster in New Jersey, USA. As the safety bars came down in front of the other passengers, Karen's snapped shut behind her. The computer sensors indicated that the safety bars were down and locked. Karen screamed to the operators, but, once started, Lightnin' Loops could not be stopped on its 30 second, 65 km/h circuit. Karen reached the top of the first loop and was tossed 23 metres on to the concrete below.

Such accidents, however, are rare. The chances of dying on a fairground ride is one in 66 million – small even in comparison with the risk of dying in a plane, which is one in five million.

Hi-tech steel allows freedom in design. At Wonderland in Canada, the Dragon Fyre combines vertical loops with a corkscrew and a helix (a screw-shaped coil).

Centrifugal force pins the passengers to the wall of the Roundup. Sometimes the floor is lowered so the passengers are left suspended in air – the force ensures they do not fall.



of speed, but by the sudden change of direction.

What comes next depends on the particular ride. With corkscrew roller-coasters, the cars hurtle up and over a complete, vertical loop. From the ground, it may seem as if the passengers are in danger of falling out. But nothing could be further from the truth. As the cars circle around, the people are actually pressed into their seats. In a similar way, water in a bucket will not come out if you whirl the bucket round fast enough. This phenomenon is called centrifugal force (from the Latin meaning 'centre fleeing').

As the centrifugal force pushes outwards, the track 'pushes' the cars in. This inward force is called centripetal force (from the Latin meaning 'centre seeking').



Hanging on

The top of the first loop in a corkscrew roller-coaster has to be quite a bit lower than the top of the slope that came before it. Otherwise the cars would not be able to gain enough momentum to get around. In the same way, any further loops must be successively lower. If the ride is long, it may have more than one section where the cars are towed back to a considerable height before being released again.

Experiencing a greater gravitational force (G force) is an important

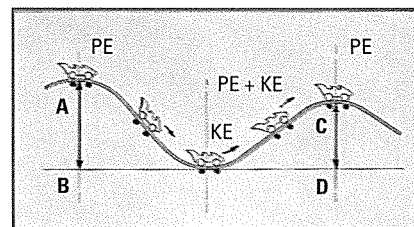
part of the breakneck thrills of a roller-coaster ride.

One G is the force of gravity we normally experience; it is what ensures that we remain planted to the ground rather than drifting into Space. On the Moon there is a force of one sixth of a G, which makes an astronaut on the Moon feel very light. A roller-coaster ride can impose a force of up to six G on the passengers. This makes the body feel extremely heavy.

On a roller-coaster ride, the pas-

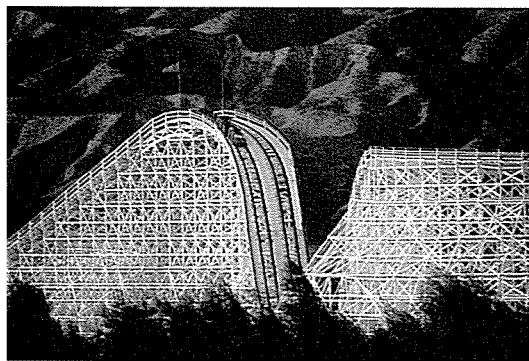
sengers only experience up to six G for a split second. Six G has a similar effect on the body to a tourniquet around the neck: it cuts off the blood supply to the head. A person can survive for only five seconds without this blood supply before he

COASTING ON ENERGY



A roller-coaster car at the top of a slope has energy. This energy can be used to move downhill at speed. This is called gravitational energy. Gravitational energy can be stored until the operator is ready to let the car go. Energy that can be stored is called potential energy (PE). Once the roller-coaster is moving, the potential energy changes into the kinetic energy of motion (KE). When it reaches the top of the second slope it changes back to potential energy again. Note that C is lower than A.

The car cannot climb to the same height as the original summit because some of the original store of energy has been lost to friction against the track and to air resistance.



Guido Alberto Rossi/Image Bank

Wooden roller-coasters cannot offer loops, but instead provide groaning timbers, sheer drops and zero gravity as the cars speed over small humps.

fall, the potential energy the cars acquired at the top of the slope changes into kinetic energy (the energy of motion). Travelling at speeds as high as 100 km/h, the passengers may go in less than one second from a downward slope of more than 45° to an upward slope of the same angle. The stomach-wrenching feeling that results is caused not by the sudden change

becomes unconscious. Death occurs shortly afterwards.

Even at two G, the blood supply to the head is restricted. When people pass out on a roller-coaster it is probably the result of the increased G force rather than shock.

The first roller-coaster was built in 1884 in Coney Island and it reached a maximum speed of only 9 km/h. Roller-coasters have adv-

The King Cobra in Ohio, is the first roller-coaster in the USA with standing room only. The cars speed down the track at 88 km/h and enter a 20 metre high, 360° vertical loop, then a 560° horizontal loop.

The Corkscrew at Alton Towers in England. Passengers travel at 65 km/h and experience a G force of 3.14 on the first drop.



Kings Island

In their efforts to come up with the ultimate experience, roller-coaster designers are even rethinking how the cars are held to the track and the passengers to the cars. One approach is to suspend the ride from the track on cables. Another is for the passengers to stand rather than sit.

Revolving room

A quite different sensation comes from being spun round and round very quickly. On a ride sometimes called the 'Roundup', people are apparently stuck to the inside wall

of a revolving room. The principle behind this is the same as that of the corkscrew roller-coaster. The wall of the ride 'presses in' to keep the passengers moving in a circle, while they are held in place by centrifugal force.

Into Space

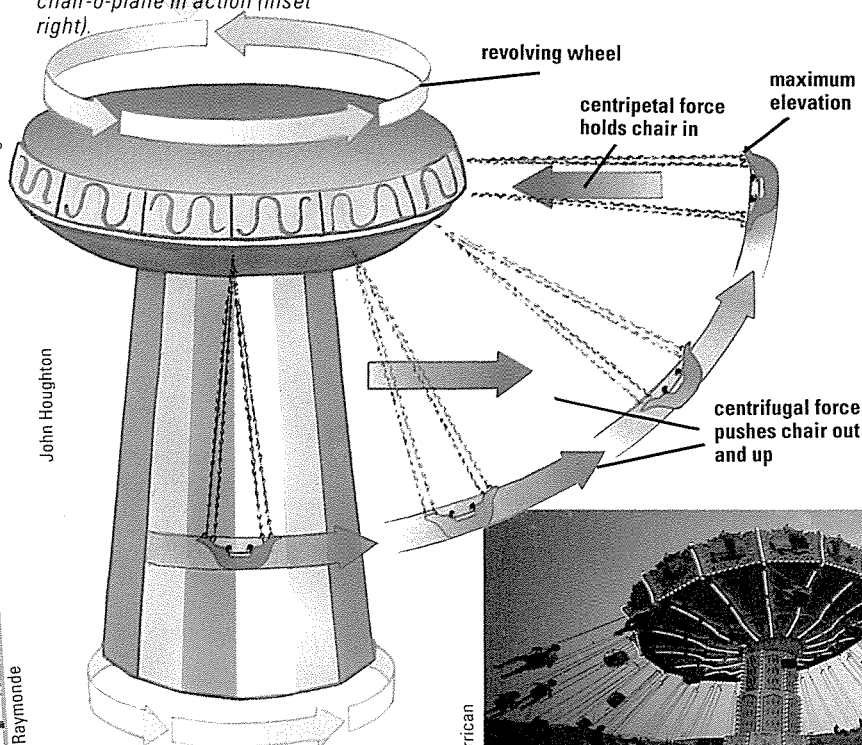
Some rides now make use of simulators, similar to those used by test pilots. One of Disneyland's most popular attractions is 'Star Tours'. Passengers take their seats in a 'shuttle' and a panel lifts to reveal the view through the forward window. The 'window' is a video screen and the spacecraft itself is a large simulator that lurches violently in time with the action on screen. Without actually going anywhere, the passengers feel they are speeding through space.

anced considerably: the Riverside Cyclone ride in Massachusetts begins with the cars accelerating from 0 to 96 km/h in just 3 seconds.

The fastest ride of all is the \$8 million Magnum XL-200, opened in 1989 at Cedar Point, Ohio. Following a vertical fall of 59 metres, the Magnum reaches 116 km/h — the speed limit for British motorways.

The record for the longest ride is held by the Beast, at Kings Island, Ohio. Its 2.25 km long track includes 244 metres of tunnels, a drop of 43 metres and a 54° banked helix.

As they spin, the chairs are flung outwards by centrifugal force. The chains, as agents of centripetal force strain against the outward push. The two forces working in opposition cause the chairs to rise. The chair-o-plane in action (inset right).

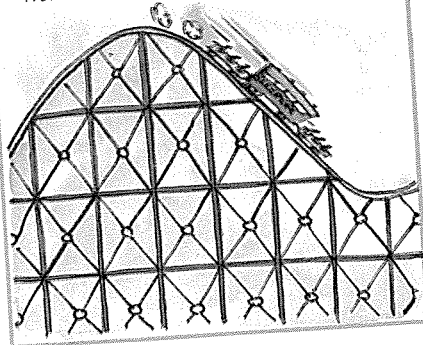


Mura/Jerrican

Just amazing!

BUMPY RIDE

IN 1983, AT PARC MELMONT, MONTREAL, DANIEL GLADA AND NORMAND ST PIERRE RODE ON A ROLLER-COASTER NON-STOP FOR THREE WEEKS.



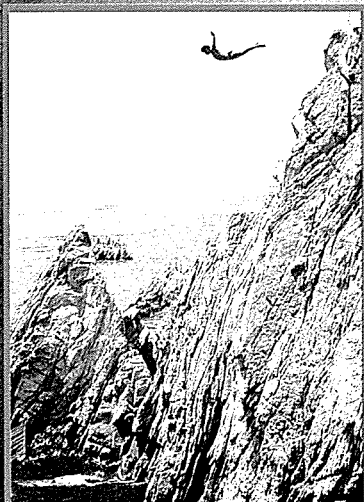
Paul Raymond





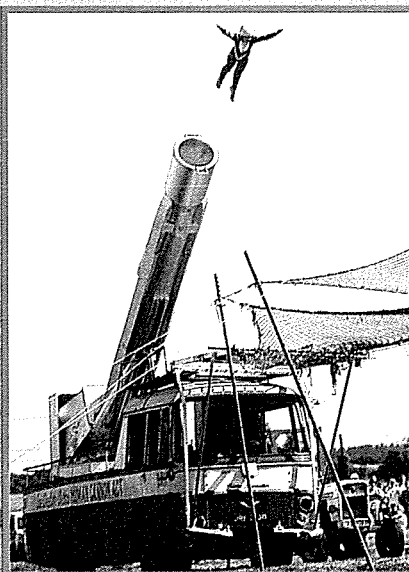
VIEW DAREDEVILS

Divers in Acapulco, Mexico, have to make an outwards to inwards turn as they fall towards the rocks 88 metres below.



Rex Features

ZEFA



Evel Knievel, here sizing up a leap at Wembley, UK, has achieved more than any other daredevil mainly because of his spectacular failures.

Human cannonball Eddie 'Old Time' Finn was fired from a safety net.

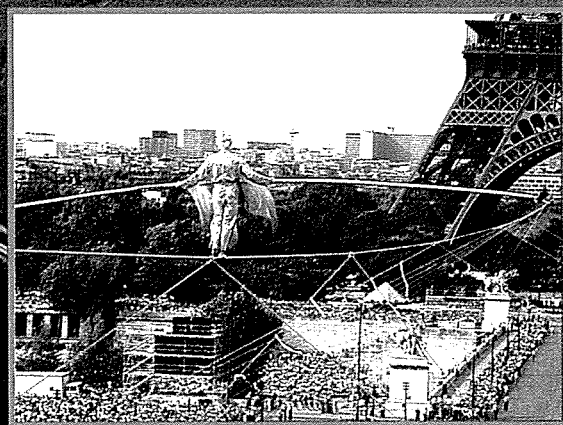
Bob Langley



Telegraph Colour Library

Stunt motorcyclist David Hodgson rides his machine through a 'wall of fire'. Travelling at speeds over 80 km/h he wears a safety suit.

The Red Arrows, in formation, are one of the most successful aerobatic teams in the world.



Rex Features

American Max Beck entered the record books for wearing a suit of 100,000 stinging bees, weighing 12.48 kg, in New Jersey, in 1987.

Tightrope walker Philippa Barker's extraordinary performance on a wire strung between the Palais Chaillot and the Eiffel Tower.

Gamma Frank Spooner Pictures

Telegraph Colour Library

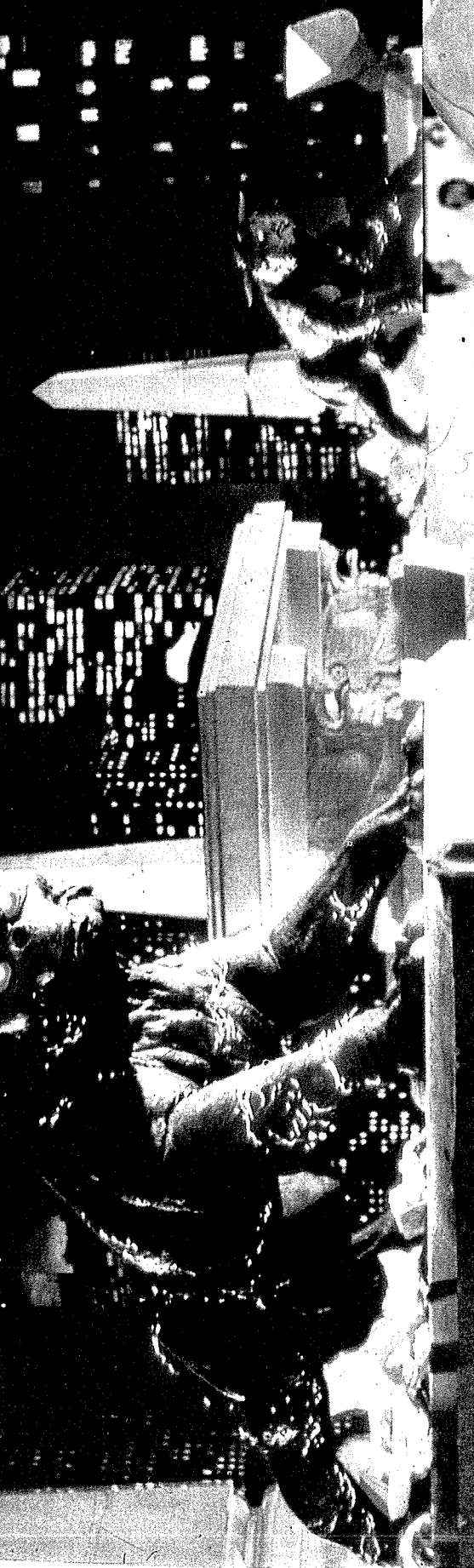


WOUNDS AND BURNS

LIVING SLIME

MONSTERS

MONSTER MOVIES



Stone gargoyles come alive at the climax of Ghostbusters thanks to the ingenuity of the modelmakers (below).

CREATING CREATURES FROM black lagoons, changing harmless-looking actors into ravening werewolves, making scars, wrinkles or rivers of slime – all are everyday work for the movie make-up men.

The art of making monster movies is to make the unbelievable seem real. Doing this is part artistry, part alchemy and part illusion. To age an actor, for example, nonflexible collodion – a liquid plastic – can be brushed on to the skin, drying and shrinking it to form wrinkles. Similarly, hair can be dyed grey or

white and restyled.

Collodion is also used to make scars but, where more gruesome effects are required, gelatin, coloured with food dye, is brushed on to the skin, then sculpted as necessary. Many of the scars, wounds and burns seen in the *Star Trek* movies were created in this way.

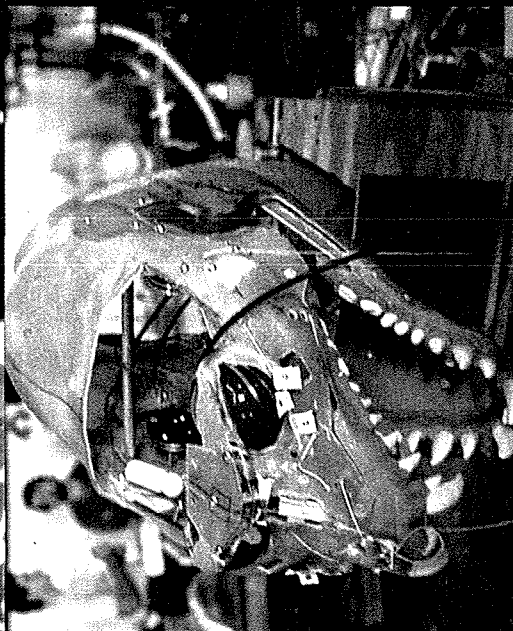


Formula blood

Fake blood is available in several forms. One of the most popular varieties is 3M blood, made by the 3M company. But dissatisfied with the way that it looked on screen,

Tom Savini, one of the leading make-up artists, created his own formula – a mixture of flour, water, red food colouring and peanut butter!

In *Ghostbusters II* the script called for a 'river of slime, which threatens to engulf the whole of New York City'. Created by special effects man, Joe Day, the 450,000 litres of slime was a mixture of liquid, vegetable-based methocel and universal food colourings. To make it 'live' as the script required 'diamond dust' – the material that gives the sparkle to metallic paint – was added and the



Columbia/Kobal Collection

Columbia/Kobal Collection





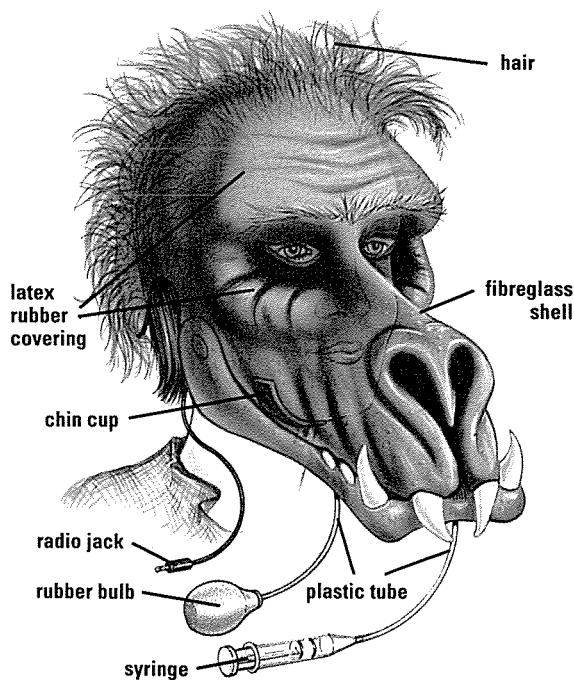
Make-up artists transform an actor into a werewolf – in a marathon 10 hour session – for John Landis's *American Werewolf* in London.



Universal/Kobal Collection

A mask is given life with a syringe-operated tube that drips 'saliva', a squeeze ball to simulate breathing and a radio jack for communicating with the film director.

Monster Mask



David Gifford

slime agitated with pumps and shot in slow motion.

The most spectacular effects, however, are nearly always illusions. For example, in *Friday the 13th* a sequence in which an axe crashes into a woman's head. In fact the sequence was made up

of three distinct shots – the screaming actress and the real axe, a foam rubber axe and a false head – intercut to create the illusion of continuity. Such sequences are known as 'continuity tricks' and are the basis for many movie effects.

When a movie calls for strange

Greek mythology in the lavish epic *Clash of the Titans*.

Other film creatures, such as the gremlins and *E.T.*, were sophisticated puppets, often with on-board computers. In *Aliens*, for example, a 4-metre puppet of the monster was moved by a network of hydraulic, manual and cable controls. In scenes where the monster was mobile a 1-metre puppet was used, operated by 49 cables, five puppeteers and four technicians.

Little secrets

Apart from the six models used for the alien, *E.T.* was played by two midgets, 78-cm tall Tamara de Treau and 86-cm tall Pat Bilson, and a schoolboy, Matthew de Merit, who played a scene in which *E.T.* is drunk.



Warner Bros/Kobal Collection

*Latex rubber, carefully crafted into custom-made masks and gloves, was used to dramatically age the characters in *Beetlejuice*.*

MONSTER SOUND

Creating all the sounds of a movie, from footsteps to screaming monsters, is the job of the 'footstepper'. He or she will record the sounds of, say, hitting a steak to simulate punches, crinkling cellophane to simulate flames, or shaking a leather glove to simulate the flapping of a bird's wings. Often animals will be recorded and the sounds distorted to create a monstrous, strange or unearthly effect. *King Kong's* earth-shattering cry, for example, was simply the sound of a lion's roar – played backwards. A 'mutant' language created in similar fashion for 1932's *Island of Lost Souls* made audiences sick!

living creatures, such as gremlins, aliens or a giant ape, then it is to the model-maker that the filmmaker turns. The oldest technique for making a model monster 'live' on screen is known as stop-motion/photography. This technique, used for the model ape in *King Kong*, involves exposing a single film frame of the model, moving it a little, then exposing another frame.

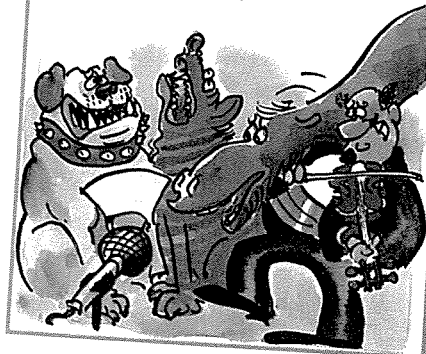
Moving models

When the film is rewound and shown at its proper speed the model appears to move. Stop-motion master, Ray Harryhausen, used this technique to create the Medusa and other monsters from

Just amazing!

SOUNDS INCREDIBLE

MGM TECHNICIANS CREATED TARZAN'S FAMOUS 'APE-CALL' BY MIXING THE SOUNDS OF A GROWLING DOG, THE HOWL OF A HYENA, THE BLEAT OF A CAMEL AND A VIOLIN!

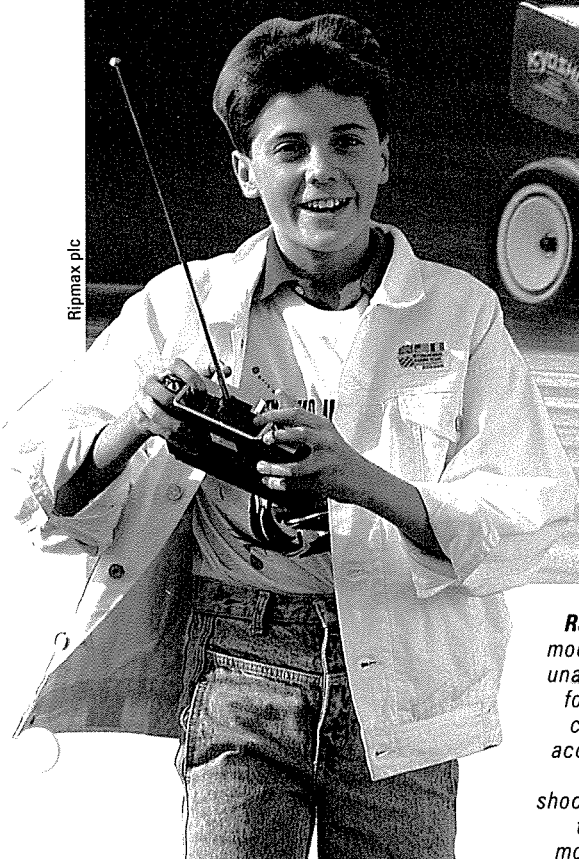


Paul Raymond



HI-TECH

TOYS



Ripmax plc

Ripmax plc

THE TECHNOLOGICAL advances that are changing our world are also finding their way into the latest toys. As a result, everything from model train-sets to ray-guns is becoming increasingly sophisticated.

Some new toys make use of microprocessors, or 'computers-on-a-chip'. These allow a variety of instructions to be stored and carried out automatically. In many cases, the built-in microprocessor can be programmed so that the toy behaves in a different way each time it is played with.

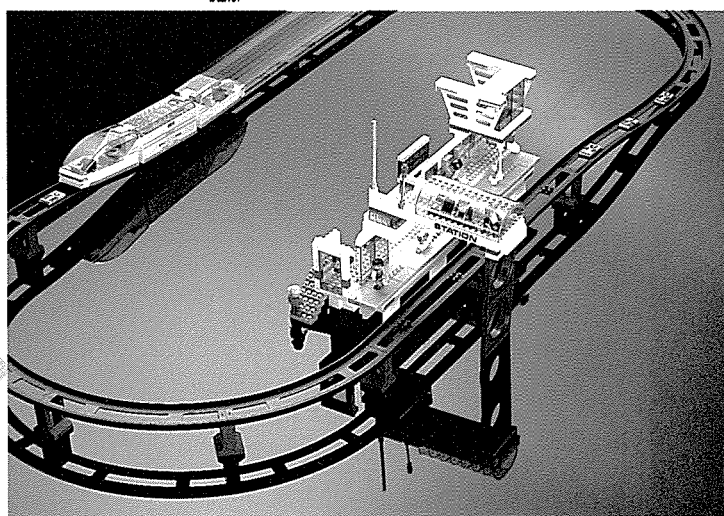
Omnibot 2000 is a programmable, remote-control robot (see Robotics, New Technology, p143). It moves over the floor on wheels and picks up objects with two mobile arms. Its memory can store instructions up to seven days in advance, and a tape recorder acts as the robot's voice box for passing on pre-recorded messages.

CompuTrain

Even train-sets have been given a 21st-century look through the use of microprocessors. CompuTrain, for instance, is a futuristic monorail,

Radio-controlled models are bought unassembled in kit form, and can be customized with accessories, such as the oversize shock absorbers on this car. Racing models can attain speeds of 45 km/h, while off-road and buggy cars are built for rough terrain.

Bar codes on the track of this CompuTrain monorail are picked up by a light sensor as the train passes over them. The bar codes give the train a variety of instructions and can be moved about the track.



the movement of which is controlled by 'bar codes' similar to those on many supermarket products. Small plastic blocks marked with various bar codes can be placed anywhere around the track. Then, as the train passes over each bar a sensor scans the pattern of bar-lines with a light beam. The sensor feeds this information to an on-board microprocessor which, in turn, is connected to a battery-driven motor, lights and a small loudspeaker. According to the message on the code, the train may stop for a few seconds before

moving on, decrease speed, reverse direction, or shut down after a certain number of passes over the bar.

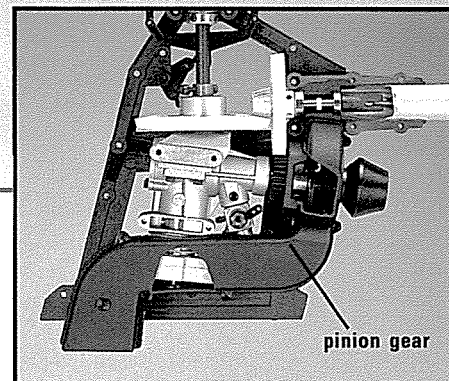
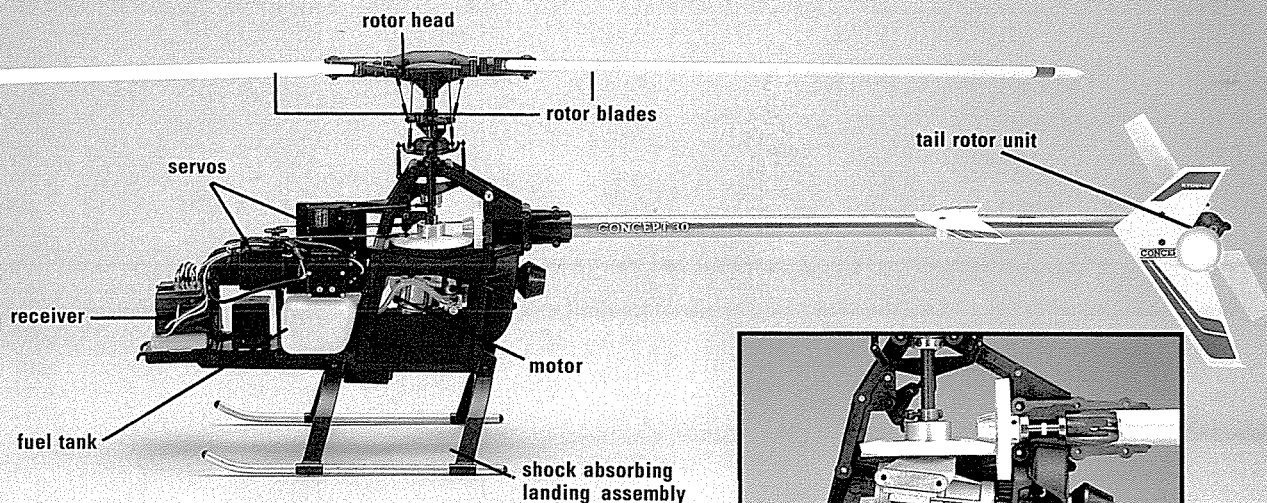
Model planes, boats and cars that can be controlled remotely have been available for a number of years. But advances in microprocessors and electronics have opened up new possibilities for the enthusiast.

Transmitting commands

Model aircraft, for example, are powered by a miniature petrol-driven engine connected by a shaft

Maison Joseph Battat Ltd, Montreal





Ripmax plc

The engine detail of this 'Concept 30' radio-controlled helicopter shows the mechanics required to fly a 2.5 kg model with a 1,160 mm rotor diameter.

to the propeller. A cable leads from the engine's throttle control to a device known as a servo that works off an onboard battery. The servo picks up signals from a hand-held radio transmitter which causes it to pull or release the throttle cable by exactly the amount required. Other servos are connected by wires and rods to the ailerons (flaps that control lateral balancing) on the wings and rudder on the tailplane.

Each servo is tuned to a slightly different radio frequency, or channel. This means, for example, that when the lever on the hand-set corresponding to the right aileron is moved, a signal goes out on the particular channel to which that servo is tuned.

Signal waves from radio-control systems can travel 2 km in the air and 500 metres on the ground. To avoid interference with emergency services, military, TV and radio

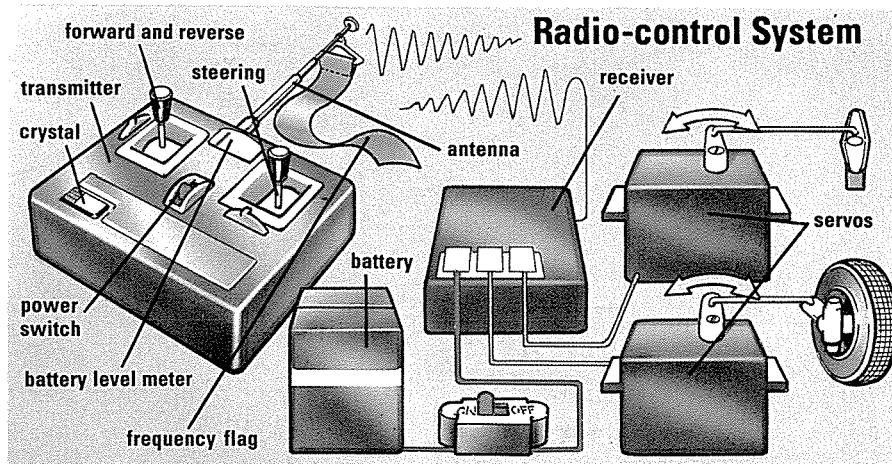
MODEL ROCKETS

Another popular hobby originating in the United States is building and launching model rockets (below). The rockets are sold ready-made or in kits, and range from small, beginner models to highly advanced ones standing over 2 metres tall. They are powered by inexpensive solid chemical boosters that supply an explosive charge at launch and a delayed burn for the ascent. The charge is set off electronically by a remote control switch that is operated at a safe distance from a miniature launch pad.

Even the smallest models can climb to well over 500 metres before returning gently to the ground by parachute. Larger, more sophisticated rockets may reach an altitude of several kilometres and can carry equipment such as a camera.



Hank Morgan/Rainbow



The main radio control system used for models is the digital proportional type. Models are directed by moving the control sticks.

broadcasts specific frequency ranges are designated for model radio control. Piloting a radio-controlled plane calls for considerable skill, especially since two or more channels often have to be operated at the same time.

Emergency landing

A special chip in the hand-set monitors all functions constantly. If there is a failure of any sort, the system sends out signals to shut off the engine and return all the flying surfaces to neutral. Any undercarriage is locked into landing position and, within two seconds, a parachute opens that brings the model gently back to the ground!

Just amazing!

MOUNTAIN HIGH

THE GREATEST ALTITUDE AT WHICH A RADIO-CONTROLLED PLANE HAS BEEN FLOWN IS 8,208 METRES – HIGHER THAN MOST HIMALAYAN PEAKS.



Paul Raymonde



NON-STOP PRODUCTION

CONTINUOUS CASTING

PAPER-MAKING

CONCRETE PLANTS

MANY AREAS OF WORK MUST be manned around the clock.

This is true not only of vital services such as national defence and emergency units, but also of much of industry where many products are manufactured non-stop.

Generating power, refining oil, producing chemicals and refining metals all involve continuous processes. In many cases, once the process has begun, a momentum is set up that cannot be easily broken.

For example, the smelting process in a blast furnace, whereby iron ore is turned into iron, is continuous. Hot metal is regularly tapped from the bottom of the furnace, and iron ore and other materials are regularly added at the top. Since the heated up furnace is

not shut down, (it may be ten years before it needs to be cooled so that its brick lining can be replaced), the smelting of the hot metal carries on day and night. Hot metal from the furnace is usually sent straight to a steel-making furnace, in a container called a ladle.



Steel refining

Continuous casting of molten steel has now largely replaced the old method of pouring the steel into moulds, then cooling, reheating and

reforming it again. It is a faster, far less bulky and cumbersome business – and wastes less steel.

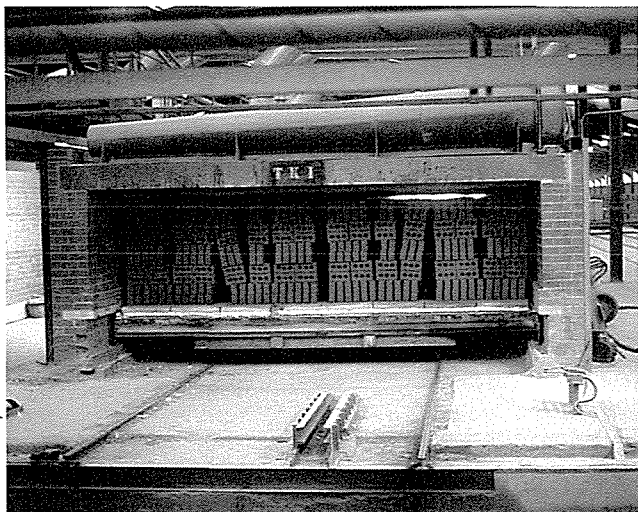
In the first stage of the refining process, steel is made in a furnace, by reducing the percentage of carbon in iron produced in a blast furnace, and then adding small amounts of other metals. There are two major methods:

- The basic-oxygen process makes bulk steels, used in consumer products, the construction industry and heavy engineering. A mixture of

Smoke streams from the chimneys of a London Brick Company factory in southern England. Brick kilns are kept going 24 hours a day because they take a long time to heat up and frequent heating and cooling would cause the linings to disintegrate.

Martin Bond/Science Photo Library





Firing bricks in a tunnel kiln. Clay bricks are loaded on to a kiln car, which slowly travels through the 100 metre long kiln. The bricks are baked by high pressure gas jets that blow down from the kiln's roof. Electronic equipment controls the baking process from beginning to end.

• The *electric-arc* method used to produce high quality steel uses only cold steel scrap of known composition. The steel is charged into the furnace and three graphite electrodes lowered through the furnace's roof. A powerful electric current creates an electrical arc that melts the scrap. Oxygen and lime extract impurities from the molten metal.

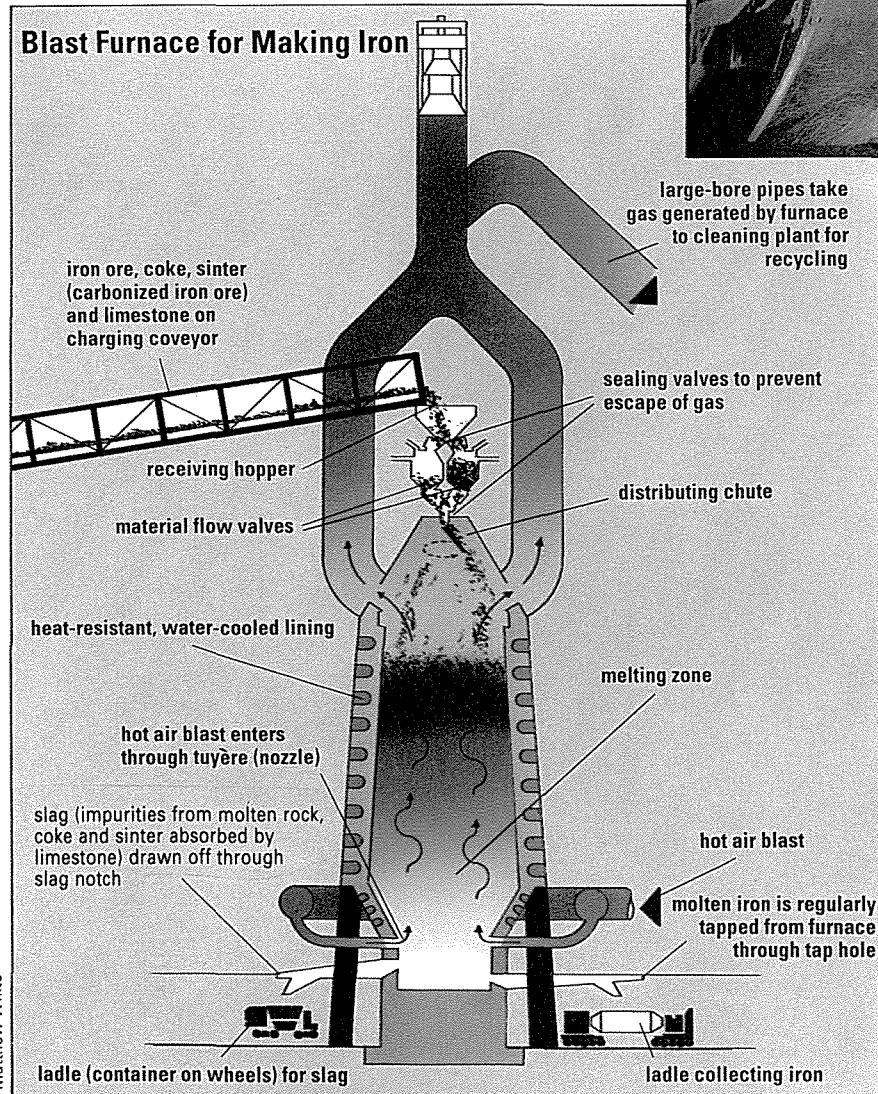
Other metals are often added to create steels with special properties. Adding 12–20 per cent of chromium, together with about 8 per cent nickel, creates stainless steel which will not rust or stain. A single melt in an arc furnace can produce 150 tonnes of high-quality steel in under 90 minutes.

molten iron and steel scrap is 'charged' (or loaded) into a furnace, called a converter, with some lime. Oxygen blasted into the molten metal in the converter burns off most of the carbon in the iron, reducing the metal's carbon content to as little as 0.04 per cent. The lime combines with impurities to form a layer of slag that floats on the hot metal. A converter can take a charge of 350 tonnes and convert it into steel in 35 minutes.

Molten iron is tapped into a trough. The hot metal runs from the trough into moulds, where it cools. Most molten iron produced by blast furnaces is sent directly – still hot – to steel refining furnaces.



Blast Furnace for Making Iron



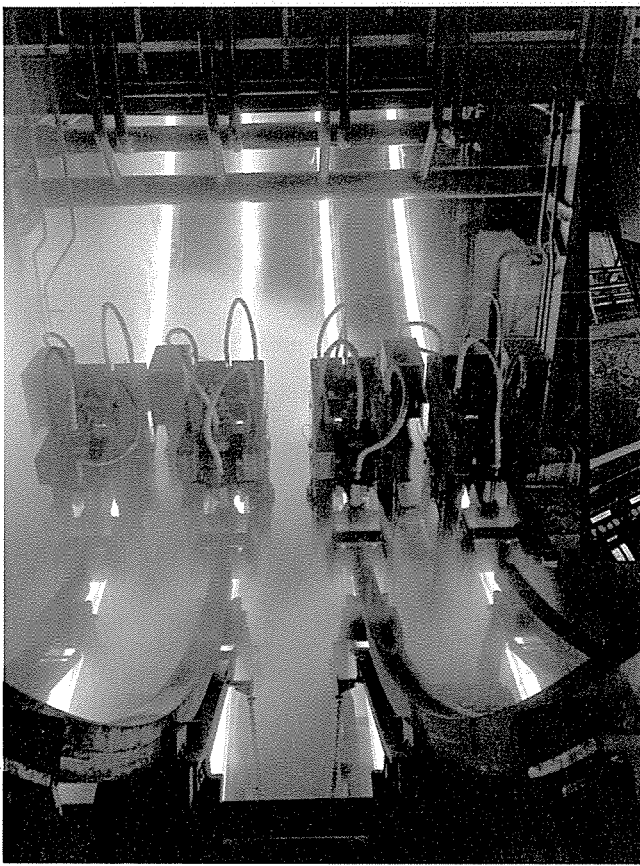
Molten steel produced by either method is tapped (poured out) from the furnace into a container called a ladle and sent straight off for further refining. This secondary steel-making is essential if a customer's exact specifications are to be met.

Hot metal

Next, the molten steel must be formed into basic shapes, called billets, blooms or slabs. An overhead crane takes ladles of steel from the converter to the continuous casting plant. The molten metal is poured into a reservoir called a tundish, which supplies the water-cooled copper mould of the casting machine at a controlled rate. The metal slowly moves through the mould cooling all the while until it leaves the other end – as

Iron ore is smelted into iron (the metal), in a blast furnace. The process is continuous. Ore, coke and limestone are fed into the top of the furnace. Melted by blasts of hot air, molten metal settles in the bottom of the furnace, while the limestone combines with impurities to form a liquid slag floating on top of the heavier metal. Both metal and slag are regularly drawn off.

British Steel plc



Tony Stone Photo Library, London

The continuous casting of standard lengths of steel is like all the other stages of steel making, monitored from the plant's computerized control room (above).

more ingredients are added to improve paper quality and colour or waterproof the paper.

The mixer produces a smooth watery pulp, which is drained over a mesh. A 'dandy' roll presses the fibres together into a wet ribbon called a web. To dry the paper, the web is conveyed by a belt through a series of steam-heated drying cylinders.

solid steel, where it is automatically cut to size. The steel goes on to be re-heated and shaped into plates, sheets, strip, beams, bars, tubes or sections, ready for sale.

Continuous-process plants use moving belts and rolls to send their product from one stage to the next. Paper-making is a good example of this. Wood is sliced into chips and treated with chemicals in a digester, where the lignin that binds the wood fibres together is dissolved, creating wood pulp, a slurry of loose fibres suspended in water.

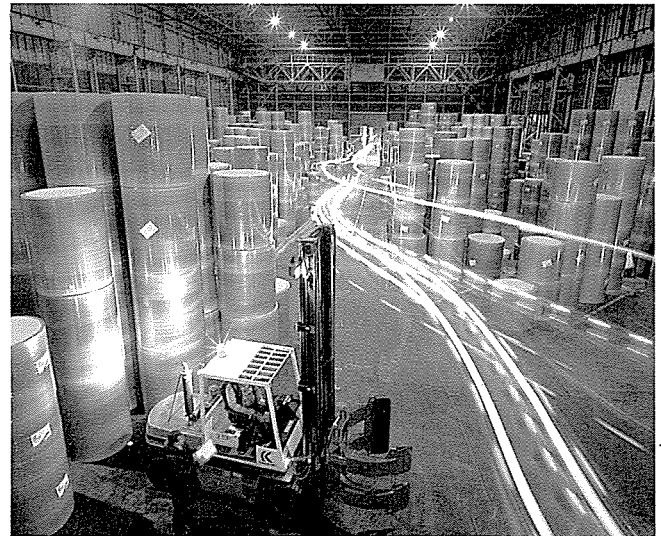


At the papermill

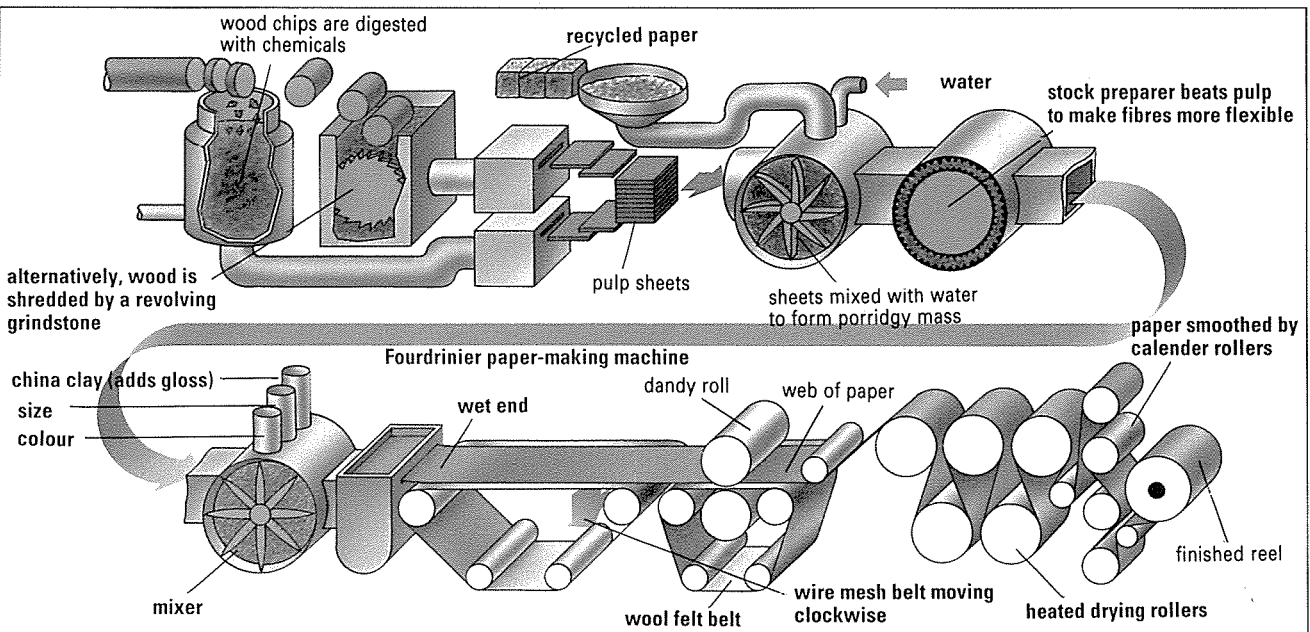
Alternatively, machines may grind logs in water to create the pulp. The pulp is sent to a mixer where

Paper in the reel store is shipped out as rolls cut down into sheets. The reels are wrapped in polythene film to prevent them being damaged by moisture when moved by clamp truck.

Paper-making is a lengthy process. Sheets of pulp are mixed with water to form a liquid, which is then converted to paper on the Fourdrinier paper-making machine.



UK Paper plc

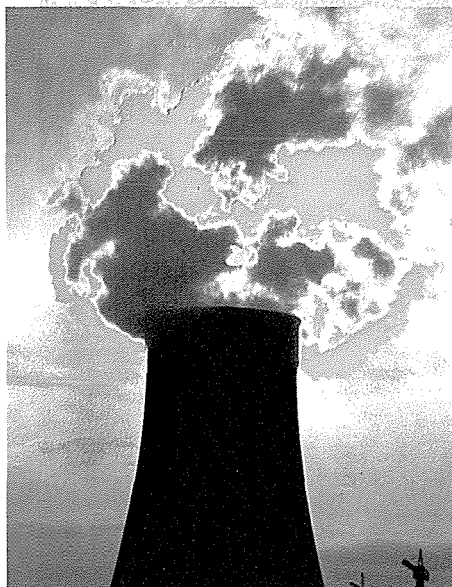


Matthew White



ELECTRICITY FROM NUCLEAR POWER

Dr Jeremy Burgess/Science Photo Library



Electricity is generated continuously in stations powered by coal, oil – or by nuclear fuel. In such power stations heat converts water to steam that drives a turbo-generator to produce electricity. In a nuclear-powered plant, the heat is produced by splitting atoms of uranium inside a nuclear reactor.

Rods of uranium inside metal cans, or pins of 'enriched' uranium that has been specially processed, are lowered into the core of a reactor. The uranium atoms are split in a process called nuclear fission – each atom produces energy in the form of heat as its nucleus splits. Under the very controlled conditions of the reactor, a steady supply of heat is generated. This heat is transferred to a boiler by a liquid or gas. Water in the boiler turns into steam that powers the turbo generator. The steam, which is not radioactive, then cools in huge cooling towers.

degrees. The mix enters at one end and travels slowly down the kiln towards the heat source, at about 30 metres per hour, passing out at the other end cooked into lumps of cement clinker, which is later crushed into a powder. The kiln is in continuous operation at temperatures of up to 1400°C, only shutting down for occasional repair.

Semi-wet process

To save energy, the wet process has been modified: the slurry is fed into filters that turn it into a semi-plastic 'cake' before it goes into the kiln, so less energy is used in drying it – 60 per cent of that needed for the wet process.

When harder raw materials – mainly limestone and shale – are used to make cement, they are ground at the first stage, before being mixed and sent into the kiln. This is the dry process.

It is not only conveyor belts and

The now dry paper continues between stacks of heavy calender rollers made of polished steel, giving the paper a smooth surface. It is then wound on to jumbo reels, each weighing about 20 tonnes, at a speed of up to 100 km per hour. These reels are transferred to the winders, where the paper is cut to order.

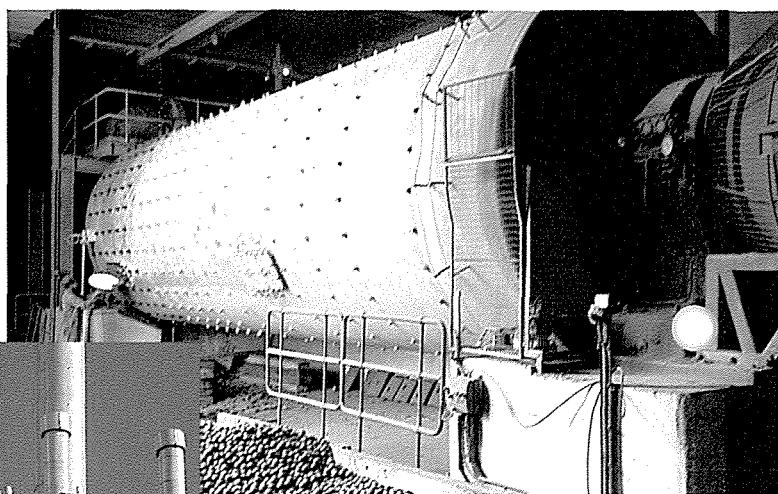
Cement, bricks and glass – all used in the building industry – lend themselves well to non-stop production. The raw materials from which they are made have to be treated in very large quantities. Setting up continuous processing systems is the most economical way of doing this.



Making cement

Cement works are often close to the quarries from which the raw materials are sent, sometimes by conveyor belt. The cement is made by either a 'wet' or a 'dry' process.

Cement clinker is ground into powder in large revolving tube mills, then pumped into storage silos (below). The cement is drawn off from the silos and either bagged or loaded directly on to lorries.



ZEEA

In the wet process, water is added to chalk to form a slurry, which is blended with clay. Some blending silos can hold 10,000 tonnes of mixed materials.

The mixture is pumped into a rotating kiln, perhaps over 240 metres long, shaped like a cylinder and tilted downwards by about two

degrees. The mix enters at one end and travels slowly down the kiln towards the heat source, at about 30 metres per hour, passing out at the other end cooked into lumps of cement clinker, which is later crushed into a powder. The kiln is in continuous operation at temperatures of up to 1400°C, only shutting down for occasional repair.



Float glass

As it floats along, the ribbon's two surfaces settle until they are parallel and absolutely flat, because the surface of the tin is perfectly flat. The ribbon is then cooled while still advancing across the molten tin until it is hard enough to pass on to a bed of rollers without the rollers marking the bottom surface.

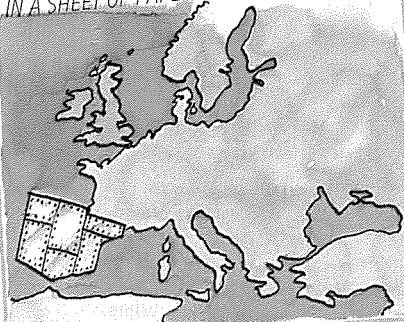
As the glass moves along the temperature-controlled rollers, it cools down further. It then passes under water jets to stress the surface. This helps the cross cutters to score the glass at the next stage, after which it is stretched and snapped off into stock sizes.

British Cement Association

Just amazing!

BIG COVER UP

NIPPON STEEL OF JAPAN IS THE LARGEST PRODUCER OF STEEL IN THE WORLD. IN 1992 NIPPON PRODUCED 25 MILLION TONNES – MORE THAN ENOUGH TO COVER ALL OF SPAIN AND PORTUGAL IN A SHEET OF PAPER-THIN METAL.



Paul Raymond



- INDUSTRIAL ROBOTS
- GUIDED VEHICLES
- COMPUTER SYSTEMS

AUTOMATION TECHNOLOGY

AUTOMATION IN INDUSTRY IS nothing new – for centuries, Man has used machines to speed up his working methods. But in the past few years, automation has taken a huge leap forward because of two things – robots and computers.

Computers have been used in industry for more than 30 years. Robots are still relatively new. But it has been predicted that there will be

Tony Stone Photo Library, London



Robots man the production line in nearly every car factory in the world. Working without break, they are ideally suited to highly repetitive tasks, such as spraying (left).

move a welding rod along a seam in what is known as continuous arc welding. Finally, robots can apply an even coat of paint from a spray gun over the body, giving a smooth finish to the end product. In some companies, robots may also be used to grind or polish car parts.

Dangerous tasks

The great advantage of robots is that they are efficient, reliable and can perform those tasks that are tedious or dangerous for humans. For example, a gigantic robot has been developed to help French nuclear engineers tighten and loosen the massive bolts holding down the lid of a nuclear reactor. These huge bolts can weigh up to 450 kg each and must be adjusted every time the nuclear fuel is replaced. While the process of unbolting and replacing the studs with manual tools took 32 hours and required the presence of eight operators, the single-operator controlled robot can complete the same job in 12 hours.

back to the computer so it knows when the robot has reached the required position. Rapid advances in technology have meant that robots with lasers are powerful enough to cut through sheet steel but also precise enough to cut the shell of an egg without damaging the delicate contents.

Robot welders

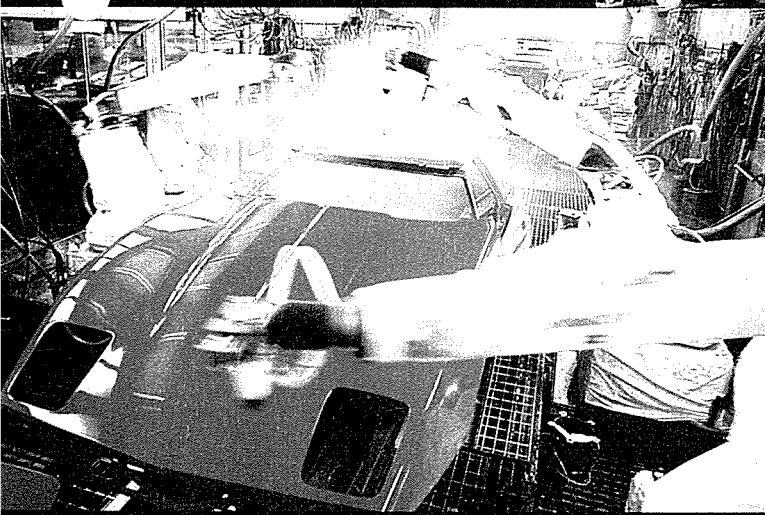
The most common use of robots today is in manufacturing, especially in the motor industry. Robots are used to spot weld panels and frames to complete the assembly of a car. A robot can also be used to

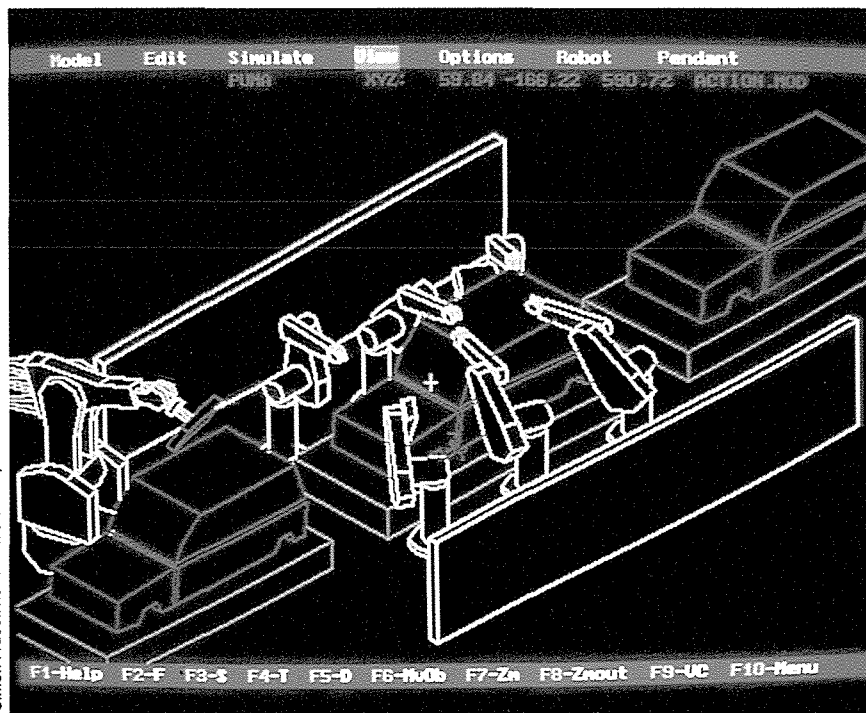
around 10 million of them worldwide by the end of the century.

Robots grew out of the development of small computers in the 1960s and 1970s. Linked to mechanical arms with motorized joints, the computers could be programmed to instruct the arm to move in a variety of ways. With different tools added, the robot arm can carry out a wide range of jobs, such as cutting, welding, polishing, painting and assembling parts.

In complicated operations, the computer calculates the angles through which each of the joints turns. Sensors feed the joint angles

Tony Stone Photo Library, London





A British-made robot was used to weld together hundreds of tubes to produce an exhaust nozzle for the Ariane-5 space rocket. This was the first time that a robot with a direct drive — that is, no gears between the motor and the welding arm — was used for welding. Such

the memory sequence of movements. Similarly, coating acrylic baths with glass-reinforcing polyester used to be a slow and hazardous process, but now a robot can spray on the three main ingredients in the required proportions.

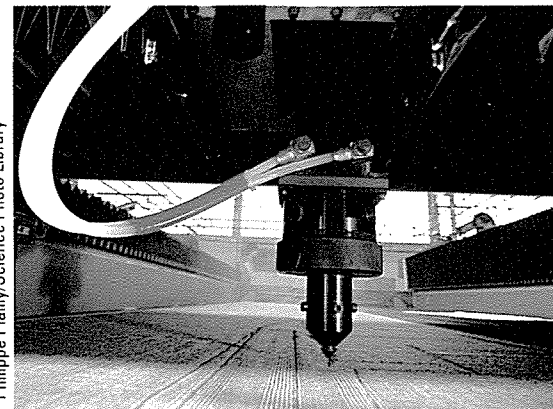
AGV

There is even a prototype robot sheepshearer. This holds the animal while robot clippers, guided by sensors, follow the line of the body.

The other major type of robot, the Automatic Guided Vehicle (AGV), is used to carry goods and components around in factories and warehouses. This robot truck follows underground cables or painted

Computer graphics are used to plan a fully automated production line, avoiding the need for wasteful trial and error when the line is built.

Laser 'scissors' can cut large amounts of fabric for clothes' manufacturers quickly, tirelessly and with great accuracy.



A robot-based workstation includes a robot arm, its control system, tools and accessories, a conveyer system for the workpieces and the instruction software.

DRIVERLESS TRAINS

Automation has replaced train drivers in some rail systems, such as the Bay Area Rapid Transit System (BART) in the San Francisco-Oakland area of California, USA. A similar system is in use in the docklands light railway in London, Great Britain. On the BART railway the trains are kept at the same distance from each other and their speeds are automatically regulated to keep them within safety limits. It is operated by two identical computers, one backing up the other. Manual controls exist if both computers fail.

direct-drive robots are smoother and more accurate than conventionally geared robots.

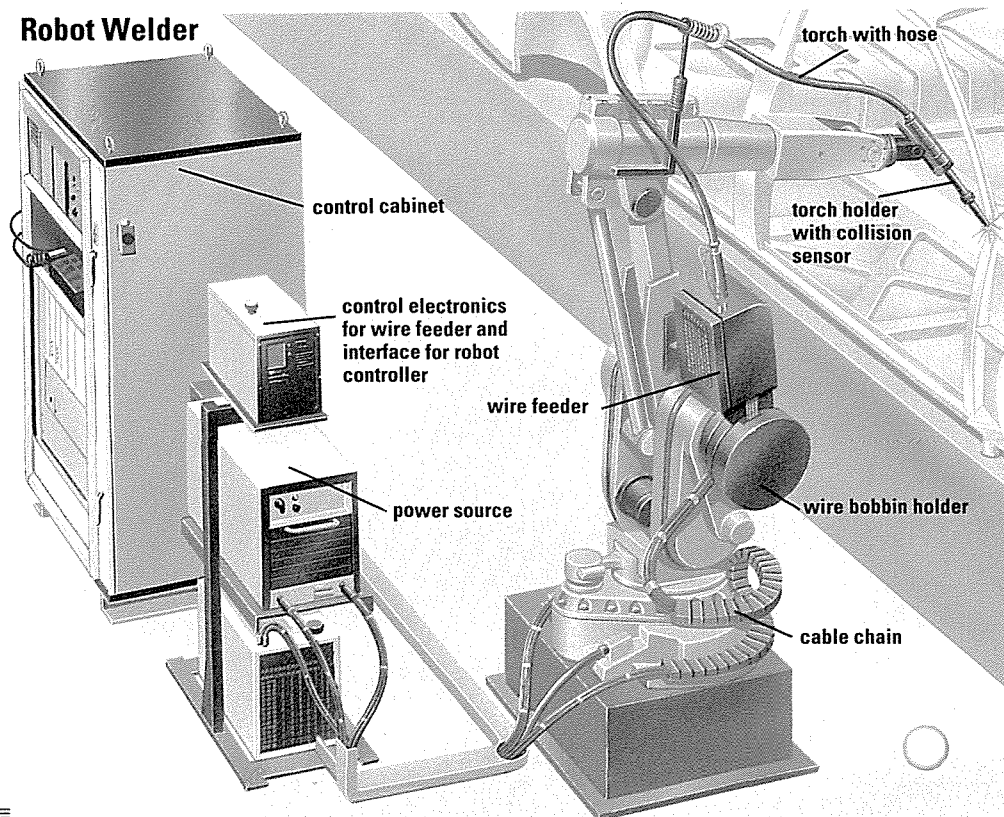
The robot carried a sensor that contained a laser and a camera eye. Together, these scanned the path ahead of the welder up to twenty times a second and fed the information back to a computer, so ensuring the best position for the robot to carry out an accurate welding seam.

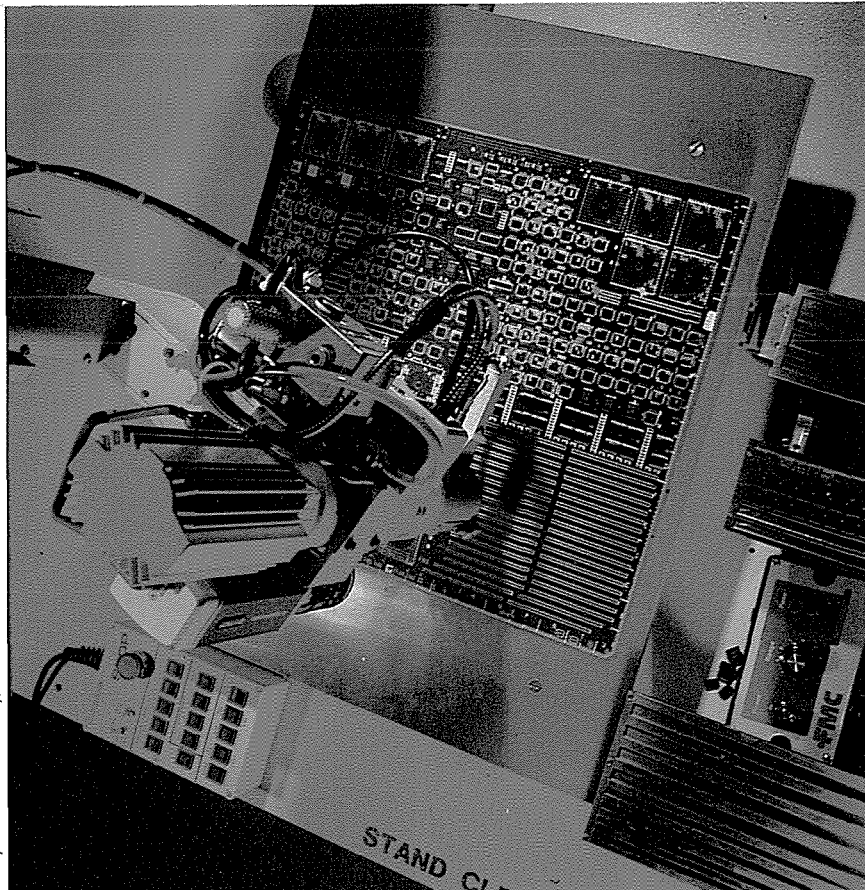
Joy-stick

Achieving a high-grade finish on a stainless-steel sink is time-consuming and can cause fatigue among workers. But it is a simple task for a robot with the right tools and a suitable program. The vital programming can be done by operators using a joy-stick to control the robot's movements, while it 'learns'

Trevor Hill

Robot Welder





AUTOMATION TECHNOLOGY

Robot reproduction is a fact of life – here the circuit boards that form the brain of future robots are automatically tested.

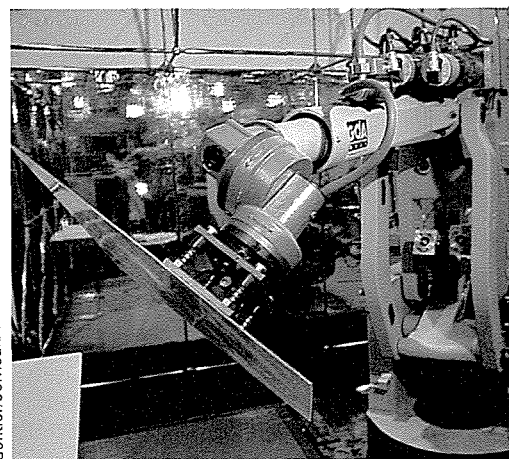
ages of different types of robot on a computer. This enables them to compare the performances and choose the best one.

Voice control

In the future, robots will receive instructions by voice. They will also be more intelligent with super computers that will enable them to interpret and carry out commands without following a rigid programme. For example, such a robot will be able to 'see' an object in its path with sensors and react accordingly. It will also be able to determine when objects on an assembly line have moved, or when to adjust a process (such as welding) automatically.

white lines. AGVs have revolutionized the tedious and time-consuming work in warehouses and stores. Some libraries now have robots that can find a selected book or videotape on the shelf and deliver it to the customer.

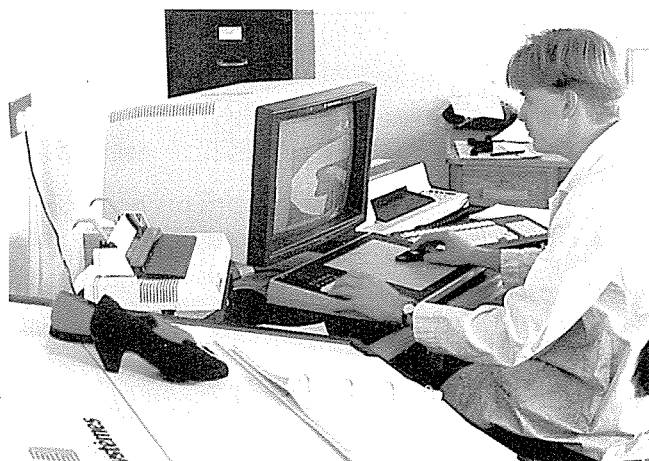
Japanese companies are turning to robots to solve problems in the country's booming construction industry. For example, robots are used to move and arrange the long, heavy steel bars needed for the foundations of nuclear power plants.



Handling goods such as sheets of glass is a task that can be left to programmed robot carriers, freeing humans for important creative or management jobs.

Designing shoes on a computer screen is fast, efficient and allows a new model to be instantly evaluated. Once satisfied with a design, the computer can drive automatic cutters and assembly machines to produce a prototype.

Gontier/Jerrican/SPL



Lectra Systems Ltd

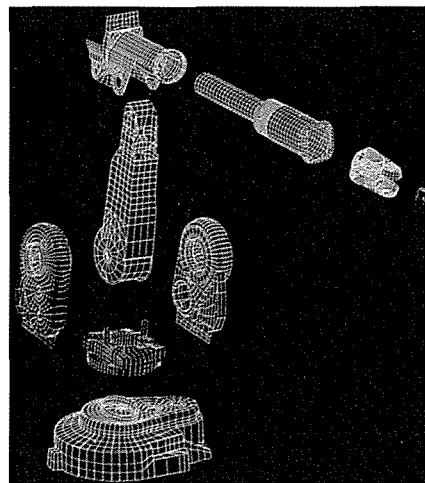


ABB Robotics

Similarly, when a dam is being built, one robot carries concrete to where it is needed, another robot assembles frames on to which the concrete is poured, then a final robot compresses the concrete. It is claimed that the robots reduce the number of manual workers needed to do the job by more than two-thirds.

Before engineers introduce an automated robot system, they create three-dimensional simulated im-

Computer-aided design is used in the development of industrial robots and the tools and accessories employed in production systems.

Just amazing!

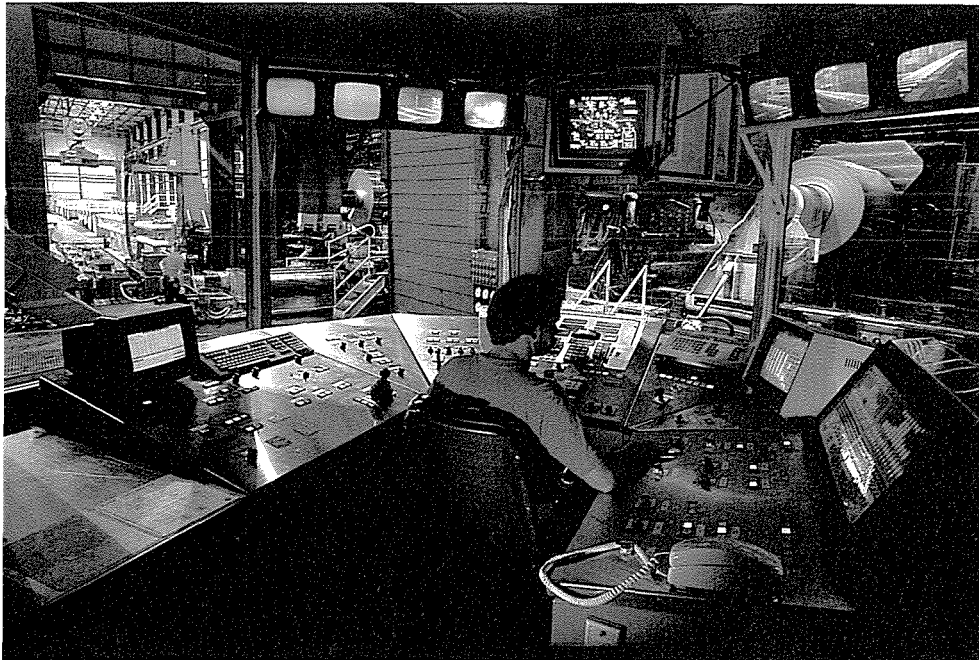
BEETLEMANIA

OVER 21 MILLION VW BEETLES HAVE BEEN BUILT SINCE 1938, MAKING IT THE LONGEST PRODUCTION RUN OF ANY CAR – AND THEY'RE STILL BEING MADE!



Paul Raymond





Tony Stone Photo Library, London

All kinds of calculations can be incorporated into the computer before a prototype is produced. This enables engineers to design products that actually take into account the automatic tools and workstations that will be used to manufacture them. The result is that modified or new products can be rapidly manufactured in response to changes in market taste.



Rapid response

Finally, all the details of sales and stock levels can be kept on computers, so that projections can be made about which products sell best. In this way, production can automatically be stepped up to meet extra demand on high-selling items or slowed if demand falls.

The fine control of parts or materials into a factory and products out, in response to customer demand, brings both increased efficiency and substantial cost savings.

Automation does not only involve robots. It has also found its way into many companies in the form of computer-aided design and supervise manufacturing (CAD/CAM). This involves using computers to design, manufacture and keep records on products as diverse as shoes or trucks. In CAD the designer works with a three-dimensional graphic model or blueprint on the computer screen. By manipulating the design, he can change things quickly rather than having to keep coming up with new designs on the traditional draughtsman's boards. Modifications to the basic design can be made with ease, and production lines changes rapidly.

The control room of an automated aluminium mill, overlooking the main production areas. The human operatives mind the machines and do the maintenance work that the automatic monitoring systems indicate is necessary.

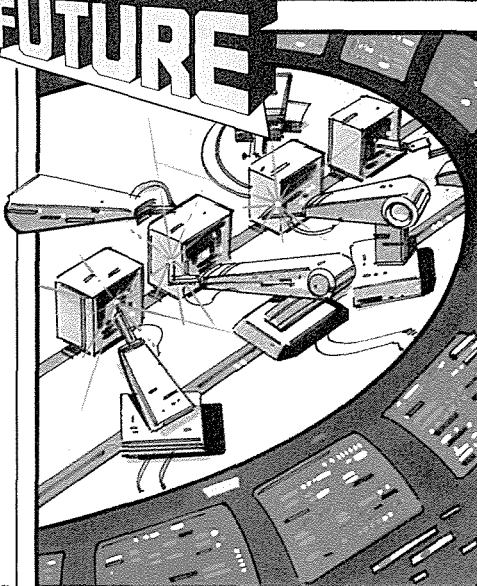
Modern printing is highly automated. This press in Singapore is fully computerized with the printers freed to keep a check on quality.



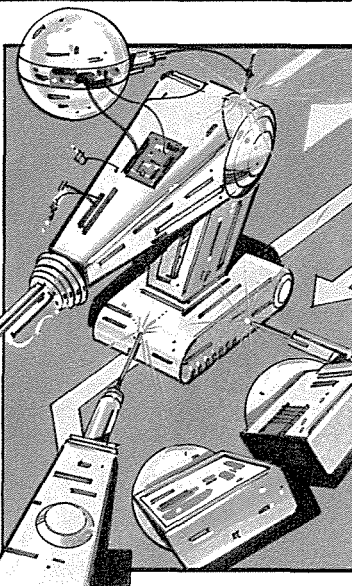
R Ian Lloyd/Hutchinson Library

INTO THE FUTURE

THE AUTOMATED FACTORY



▲ In the factory of the future 'intelligent' computers will keep a watchful eye on the working robots, freeing humans for all-important planning.



▲ In the event of breakdowns, substitute robots will be installed on the line and the faulty robot sent to the automatic 'troubleshooting' repair station.



▲ In the event of an emergency such as a fire, robot fire-fighters, having automatically sensed the source, will move in and tackle the problem.



Q IN THE AIR
Q UNDERWATER
Q FROM SPACE



Pascal Rondeau/Alisport



ESCAPE!

Formula 1 racing cars are designed with safety in mind. Immensely strong carbon fibre/Kevlar one-piece chassis, roll-over bars, a six-point harness, automatic fire extinguishers and built-in oxygen supply combine to help the driver survive (inset) even the worst crashes.

HIGH-SPEED CIVIL AND military transportation is fine — until, that is, something goes wrong. Then, efficient and effective methods of escape become essential.

One of the most dramatic methods of escape is the ejection seat provided for pilots and co-pilots of military jets. Once activated, it shoots its occupant out of the cockpit in less than half a second. A small rocket motor underneath then fires to blast the seat several hundred metres clear of the aircraft, then an automatic parachute system is deployed.

Once safely down, however, the crewman's problems may not be over. If he bailed out over the sea or a remote region of land, any rescue could still be many hours away. To help him stay alive until then, the seat pan of the ejection seat contains an inflatable dinghy together with a variety of survival aids.

Pressurized cabin

Passengers of a stricken airliner have no way to escape while in flight. Since the cabin is pressurized, even the smallest opening between the cabin and the outside could prove disastrous. The violent





Martin-Baker ejector seats have saved well over 5,000 lives. The Mark 10 version, being tested on a rocket-powered sled (above), is fully automatic.

rush of escaping air would suck absolutely any objects nearby that were loose — including passengers — out through the gap. Thus, it would be impossible, for instance, to open a door to let people attempt a parachute jump.

Oxygen masks

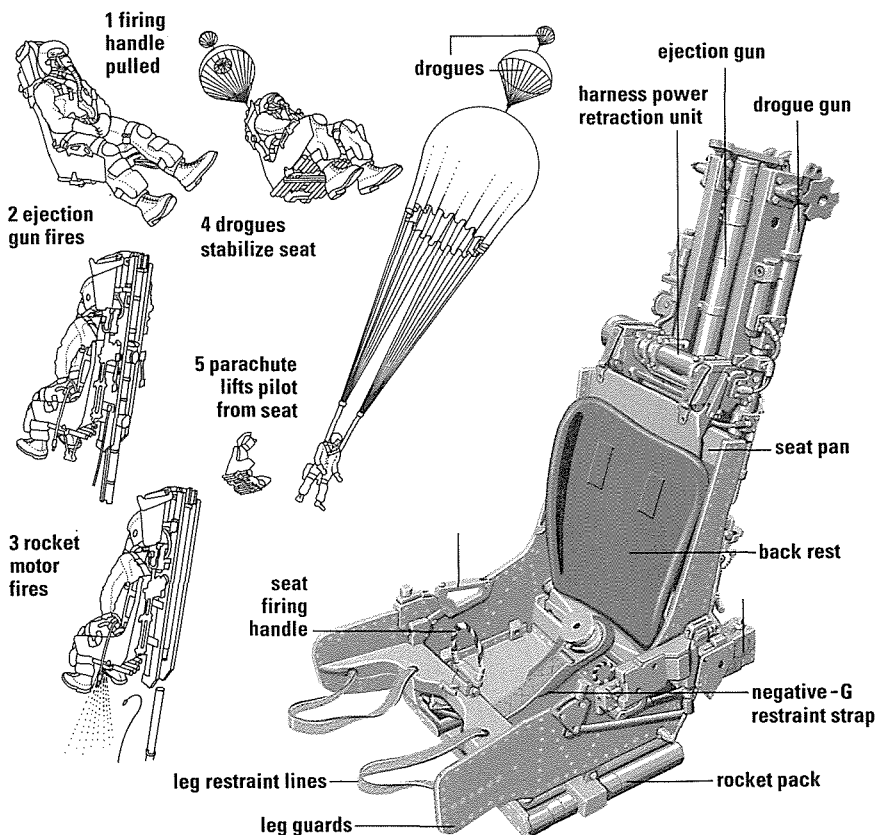
In the event of a drop in cabin pressure, oxygen masks are released from the bottom of the luggage rack over the passenger seats. These allow passengers to continue breathing normally until the aircraft can make an emergency landing.

Once on the ground, it is vital that any survivors get clear of the plane as soon as possible since leaking fuel can quickly ignite and turn into

a deadly fireball. Also, if a fire breaks out inside it will fill the passenger cabin with choking smoke and intense heat. Emergency procedures must provide for the complete evacuation of the aircraft within 90 seconds.

As well as the regular doors, airliners are equipped with emergency exits over the wings and

In case an airliner has to ditch in the sea, life-jackets are stowed under each seat. These simply fit over the head and tie around the waist. Some self-inflate when a toggle is pulled, others have to be blown up by the wearer. A water-activated flashing light fitted to the vest is intended to help rescue teams locate anyone floating near



Martin-Baker Aircraft Co Ltd/Trevor Hill

at the back. These, however, are high off the ground — 5.8 metres in the case of a Boeing 747.

Inflatable chutes

To enable a fast but safe evacuation, canvas chutes are automatically unfurled and inflated from the base of the doors in an emergency. Passengers then jump out and slide down the chutes to safety.

Life rafts are self-inflating and can carry up to 20 people. They are equipped with rations, water, medicines and fishing gear.

SHUTTLE EJECTOR

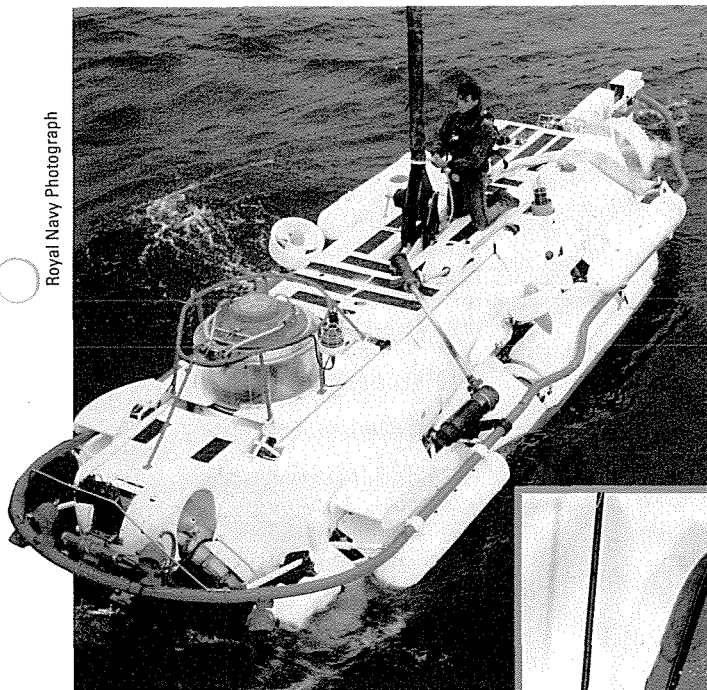
Following the tragic explosion of *Challenger* in which seven crew members died, a new method has been devised for astronauts to escape from the Space Shuttle orbiter in an emergency. For the system to work, the orbiter must be in stable gliding flight in the lower atmosphere (6,000–9,000 metres). First, explosive bolts blow out the entry hatch on the Shuttle's mid-deck, and then a 4-metre long telescopic pole extends from it. Wearing their escape backpack, the astronauts take it in turns to slide along the pole and out into the air. The pole carries them clear of the craft, and their parachutes deploy automatically. For escape over water, the backpack includes a life raft.

the wreckage. In addition, each passenger seat can itself be used as a flotation device and the airliner carries several giant inflatable life-rafts equipped with survival aids.

Flotation device

When a ship goes down or when people are washed overboard, some kind of lighter-than-water support is essential. The simplest survival aid is a life-vest that is filled





The LR5 is used by the British Navy to rescue crewmembers from disabled submarines. In an emergency, a special, inflated life-jacket (below) is used to surface freely from up to 180 metres.

ESCAPE!

Deep-sea divers

Divers who may be working deep under the sea when an oil rig or offshore platform has to be evacuated also need a means of escape. They cannot simply come to the surface unprotected or they will suffer the excruciating and often deadly condition known as the 'bends'. (This happens when dissolved gas in the diver's blood expands to form bubbles as the outside pressure drops too rapidly.) Normally, divers spend up to several days in a decompression chamber after long periods deep underwater. But in an emergency, a special,

The US Navy's DSRV – Deep Sea Rescue Vehicle – being loaded into an Airforce C5 during a training exercise to rescue stranded submariners.



Royal Navy Submarine Museum, Gosport

with foam and worn like a waistcoat having straps to secure it.

This stops a person from actually sinking but it does not hold the face of someone who is unconscious clear of the water. For this reason, a life-jacket, although bulkier and less comfortable, is much safer. It fits over the head and is inflated either by blowing air in through a short pipe or by releasing pressurized gas from a gas bottle inside. Military versions inflate automatically when a special sensor detects water.

Survival at sea

For long-term survival, and even for short-term survival if the sea is very cold, a life-raft offers the greatest advantages of all. It keeps its occupants relatively dry and provides for the stowage of food, water and equipment such as a radio transmitter and flares. Inflation is rapid and automatic by way of built-in gas canisters.

A totally different vessel is needed for workers trying to escape from a burning offshore oil rig. As

Inflatable chutes are the standard escape device for civil airliners – passengers slide down to safety.



Just amazing!

FALLEN ANGEL

WHEN A DC-9 AIRLINER WAS BLOWN UP IN MID-AIR IN JANUARY 1972, VESNA VULOVIC, A YUGOSLAV AIR HOSTESS, FELL 10,000 METRES IN THE WRECKAGE – AND SURVIVED.



Paul Raymond



Quadrant Picture Library

the flaming oil spreads out across the water it turns the surface of the sea into a hot inferno from which no ordinary rubber and canvas lifeboat could offer protection.

Fireproof capsule

The only way out then is with a fireproof survival capsule that can be lowered into the sea from the side of a rig. Each sealed metal

reinforced lifeboat, containing a decompression chamber, is lowered down so that the divers can rapidly get away from the danger area.

Escape from damaged or crippled submarines is especially dangerous because of the potentially huge water pressure outside the vessel. A submarine can get into difficulties, for example, if its propeller becomes fouled or its hydroplanes



The Shuttle
escape hatch
provides a means
of escaping from
the craft, should it
become disabled.

Another escape
procedure involves
the use of an
escape pole
(below). Much crew
training since the
Challenger tragedy
has centred on
ways of surviving
possible future
catastrophes.



Navy, known as LR5, is lowered into the water from the ship and then manually steered to its target.

Submersibles

A metal funnel underneath, called a transfer skirt, fits securely over the emergency hatch of the sunken sub and provides a way for crewmembers to transfer to the submersible for their journey back to the surface.

The US Navy employs a deep submergence rescue vehicle (DSRV), which is carried to the scene of the emergency on the back of another submarine. Like the LR5, it descends and links up with the emergency hatch of the sunken sub via a transfer skirt. Up to 24 people can escape at one time in the DSRV, which continues to travel back and forth until all of the crew is rescued.

Submarine systems

Although it has performed exercises with rescue vehicles, the British Navy has concentrated its efforts on developing an escape system for crewmembers of disabled submarines. This uses a special life-jacket that looks like a large hood and is secured to the crewmember's waist. Entering the escape tower, he plugs into an air-supply socket to inflate the life-jacket. Once the chamber is flooded it is opened and he simply rises freely to the surface, from depths of up to 180 metres, breathing normally as he goes. This system is not, of course, without its dangers. Rising freely from depths of 180 metres exposes the submariner to the 'bends' and nitrogen narcosis (a poisoning effect that results in dizziness or sickness).

are damaged so that surfacing is impossible. Or, during a conflict, a submarine can be crippled by an enemy mine or torpedo.

Once the vessel has settled on the seabed, its crewmembers have one of two options. In fairly shallow waters, they can try to escape from the emergency hatches and swim to the surface. At greater depths, a radio buoy has to be sent up to transmit an emergency signal.

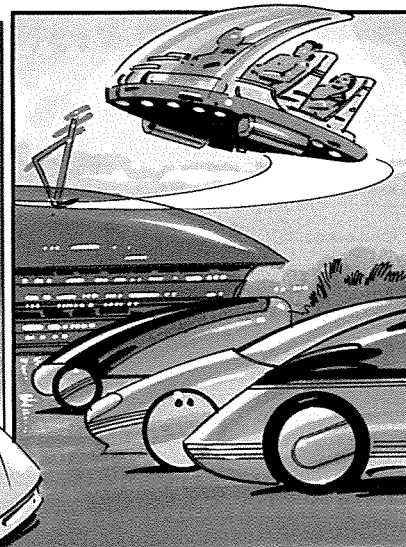
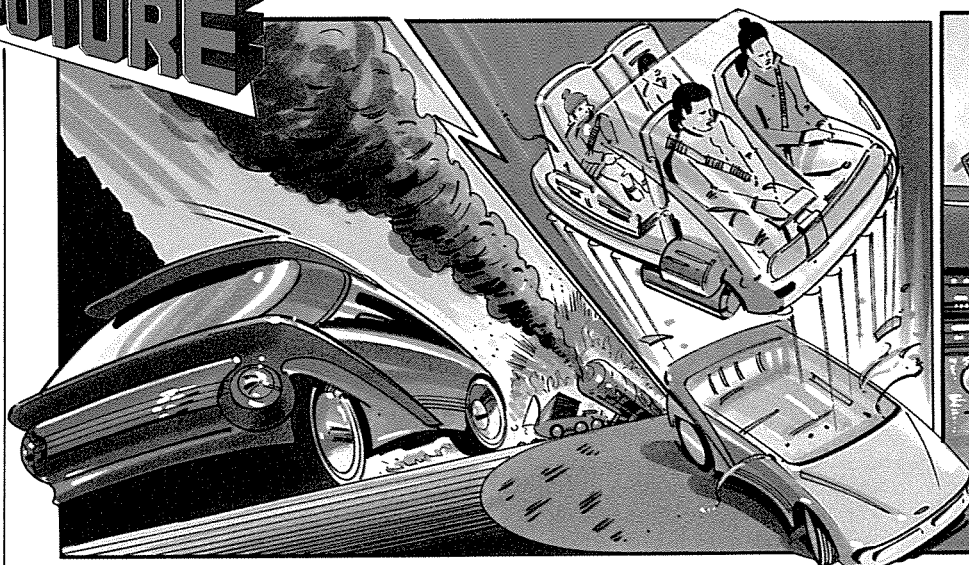
A surface vessel or a second submarine may then come to help carrying a small rescue submersible. One type used by the British

Gamma/Frank Spooner Pictures

Gamma/Frank Spooner Pictures

INTO THE FUTURE

AUTO-EJECT SYSTEM



▲ Approaching danger, the car of the future will be equipped with an intelligent escape system that will sense when a serious impact is unavoidable.

▲ The roof section will be jettisoned and tiny rockets installed in the ejector seats will fire, taking the occupants up and away from the scene of danger.

▲ The self-steering, rocket-powered seats will fly the occupants to safety where they will take directional instructions from the driver and land where required.

Joe Lawrence



■ TACTICS

■ FOREST FIRES

■ BLOW-OUTS

FIGHTING

FIRE IS STILL THE GREAT destroyer. But armed with the latest fire-fighting equipment and fire-suppressing chemicals, Man now stands a better chance against this formidable natural enemy.

The most commonly seen fire-fighting appliance is the water tender. Equipped with a pump and 9- or 14-metre ladder, it carries over 1,800 litres of water. At the scene of an emergency, firemen immediately look for the nearest fire hydrant. In some countries, including Great Britain, its position is indicated by a yellow plate bearing an 'H'.



Water supply

A standpipe (a vertical pipe, in which water rises) is fixed to the hydrant and a hose is then connected to this to provide an unlimited supply of water. In country areas, water may be pumped out of

London Fire & Civil Defence Authority; Rex Features Ltd

Fire spreads rapidly through a skyscraper, leaping from floor to floor along service ducts that carry wiring, plumbing and air conditioning. Firemen must carry their own supplies of oxygen (above) so that they do not inhale toxic fumes or smoke.



PUTTING OUT CHERNOBYL

When Reactor 4 in the nuclear power station at Chernobyl, in the USSR, exploded in April 1986, it started an horrific fire. At first local firemen tried to douse the flames with water. But the intense heat of the burning reactor core – up to 2,700°C – instantly turned the water to radioactive steam that rained down on the fire-fighters. In the end, the fire was only put out when helicopters dropped 5,000 tonnes of sand, clay, lead and boron on to the blazing power station. Radiation levels were so high that each pilot was only allowed to fly 22 missions.

David Hodgson/Telegraph Colour Library

An asbestos suit, coated with aluminium, allows a fireman to get to the heart of a blaze – in this case on an oil rig in the Caspian Sea.

a nearby pond or stream. The supply in the tender is only used as a last resort.

Another standard appliance, the turntable ladder, can rotate and extend to a length of 30 metres. From the top of the ladder, a fireman is able to spray water down on to the flames below or to rescue people trapped high in a multi-storey building.

A hydraulic platform, in some

Foam sprayed on to a burning aeroplane floats on the surface of the burning fuel and so smothers the flames. The foam is generated when air sucked in at the side of the hose nozzle aerates a fast-moving stream of foaming agent and water.

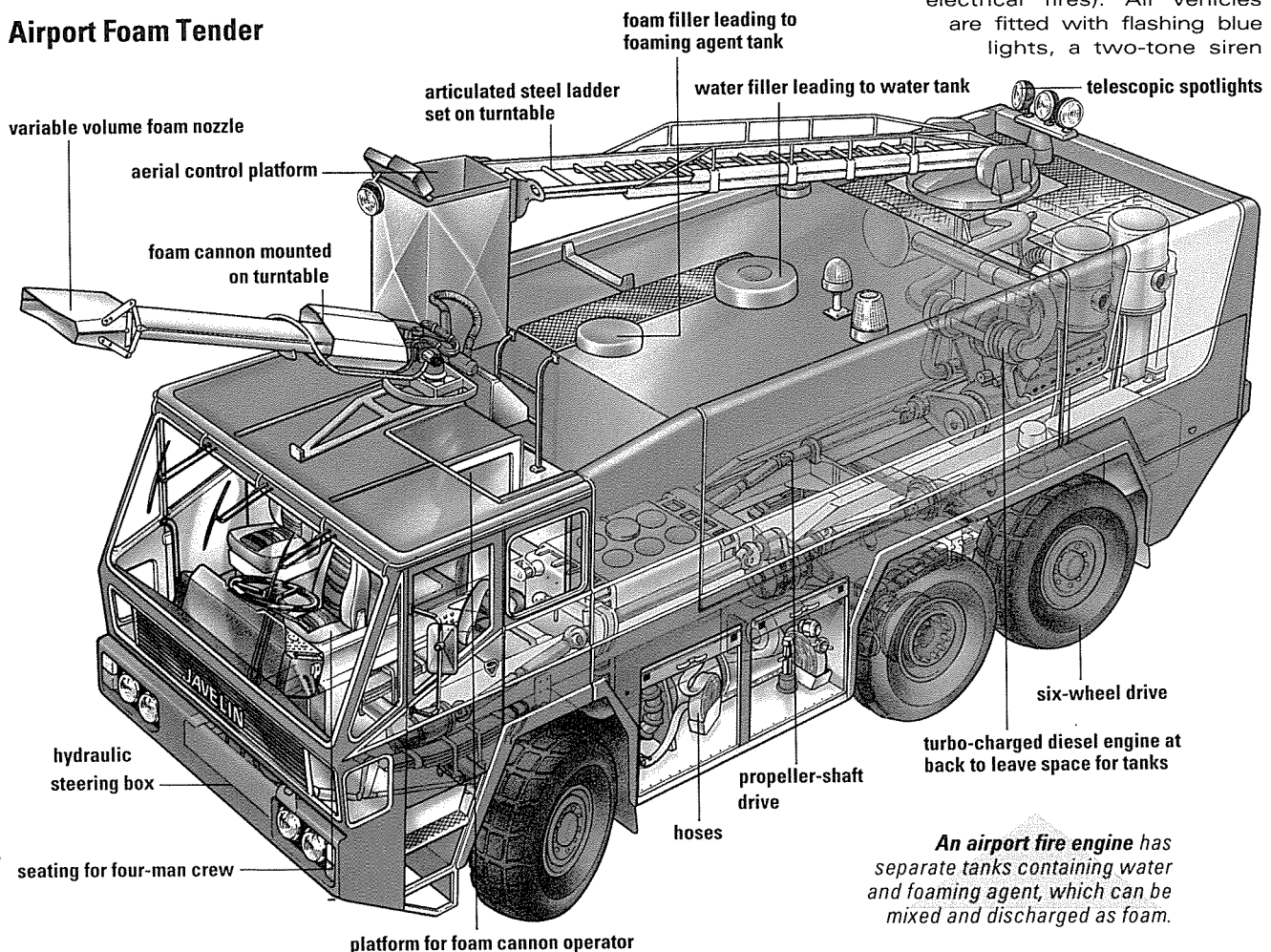


cases, may be called upon instead. This has a long, powerful arm, capable of bending at different angles, with a cage at the end. Up to four adults can fit in the cage at once, while an operator, either on the ground or inside the cage itself, can direct a jet of water through a large attached nozzle.

Smaller vehicles available to the fire service may carry cutting gear, winches and carbon dioxide gas or dry powders (used as an alternative to water or foam in, for example, electrical fires). All vehicles are fitted with flashing blue lights, a two-tone siren

Gamma/Frank Spooner Pictures

Airport Foam Tender



An airport fire engine has separate tanks containing water and foaming agent, which can be mixed and discharged as foam.

John Houghton



The Yellowstone Park forest fires in 1988 were the largest fires ever known in the USA. This image taken by satellite Landsat 5 from a height of 705 km shows burned areas as magenta, fires as orangey-brown and smoke as blue.

through the hoses. Nozzles called monitors can be set up on the ground to shoot out arcs of foam over 20 metres high. If larger quantities are needed, specialized foam tenders are sent to the accident scene. These are equipped with a huge fan that can blow foam down a wide flexible pipe in order to reach inaccessible places.

Every major airport has its own

HIGH-TECH PROTECTION

Computer programs that simulate the progress of fires in buildings are used to reduce the risk of a real one spreading. Information on rooms and exits, furnishings and the location of occupants is fed into the computer. The program shows how quickly a fire will take hold, and other details, such as where best to position fire doors to stop it spreading.

fire-fighting appliances, including large foam tenders, in a building close to the runway. Even in the event of a minor incident where fire has not actually broken out, a plane may be sprayed with foam as a precautionary measure.

Researchers are trying to develop an additive to aircraft fuel that will prevent it exploding during an accident. A chemical known as Avgard



Alan & Sandy Carey

Fire fighters protect poles carrying power lines through Yellowstone Park from an approaching fire by wrapping the bases with foil.

that start at the scene of road, rail and aircraft crashes when fuel tanks are ruptured and explode. Since the still-burning oil or petrol would simply float to the surface of any water that was sprayed on to it, foam is used instead. The foam acts as a blanket, smothering the fire by preventing fresh oxygen in the air reaching it.

All water tenders carry a small quantity of liquid foam in drums, which is mixed with air as it passes

Helicopters were used to scoop up water with special buckets (below) from lakes within Yellowstone Park and drop their load on smaller fires as they broke out.



Alan & Sandy Carey

and a radio to keep in constant touch with central control.

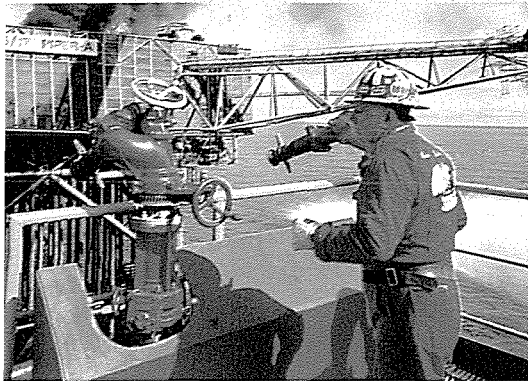
The call from the regional control centre to a local fire station gives details of the fire, its location and the appliances that are needed. At a very large fire, a mobile control unit may be set up to co-ordinate resources and provide a radio link with central control. The officers in the control unit decide on fire-fighting tactics, allocate jobs to the appliance crews, and arrange for relief personnel, if required.

Foam tenders

Fires that involve burning oil or petrol have to be treated in a special way. These are the kinds of fires



TROUBLESHOOTERS – TO PUT OUT OIL-RIG FIRES



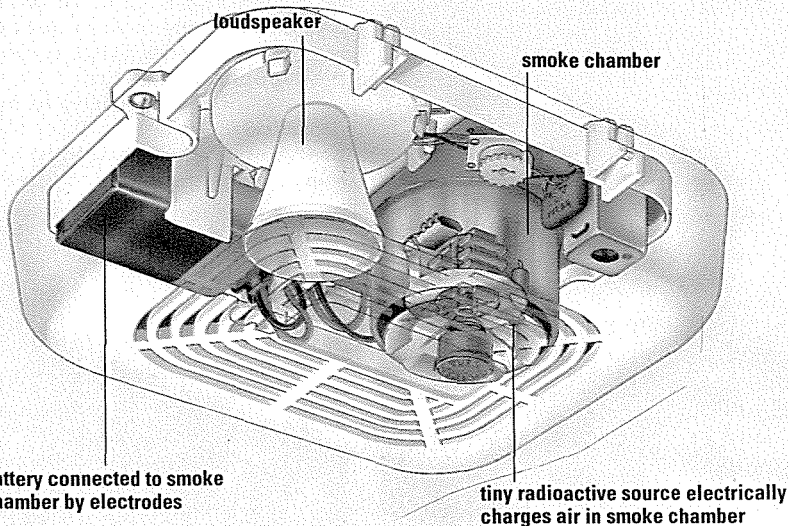
Tackling major fires and blow-outs at oil rigs is a task for specially trained teams of troubleshooters. A legend in this business is the Texan Red Adair, seen here tackling an explosion on the Piper Alpha oil rig in the North Sea that killed 167 men in 1988. His company, whose motto reads 'around the world around the clock', deals with around 30 serious oil-rig accidents each year. In one incident, he and his men put out 16 wells burning on a platform in the Gulf of Mexico by building special rafts to get them within 100 metres of the blaze, so they could deluge it with water.

Rex Features Ltd has proved promising in trials. At the same time, work is going on to make seats and on-board equipment more resistant to fire and less likely to give off toxic fumes when burning.

After a long period of drought, the smallest spark is enough to set huge areas of forest-land ablaze. In

The alarm in an ionization smoke detector is set off when smoke from a fire reduces the electric current in a special chamber in the detector.

Ionization Smoke Detector



Steve Cross

the summer of 1988, Yellowstone National Park in Wyoming, USA, was parched through lack of rain. In August, lightning started a number of forest fires that quickly spread, fanned by gusts of wind. Suddenly, the situation was out of control.

Firelines

To put out a major forest fire with water is virtually impossible unless heavy rain falls. The only effective approach is to try to confine the damage to a certain area.

In some cases, the fire-fighters at Yellowstone felled broad strips of forest to deny the approaching fire a fresh supply of timber. Making

these firelines also involved removing the top layer of soil which was rich in inflammable, partly-decayed wood. As a final measure, back-fires were lit on purpose to burn out the area between the firelines and the oncoming blaze.

'Spot fires' were another problem for the 9,500 workers trying to quell the Yellowstone inferno. These were started by branches or other burning debris, carried by the wind from a major fire to a nearby region of untouched forest. By the time the Yellowstone fires died down, in



London Fire & Civil Defence Authority

A hydraulic platform with three booms can be operated in very confined spaces – it will even go over obstructions and down the other side.

the top of the well. While hoses damp down the flames, an explosive charge is gently lowered from a boom until it is about 3 metres above the well-head. The charge, which is remotely detonated, blasts gas and oxygen away so leaving the fire with nothing to feed on – thus the fire is extinguished. The final step is to cap the well-head with a valve to prevent further gas from leaking. Fires on oil platforms at sea are even more difficult to control. Fire-fighting ships pump out massive jets of seawater to subdue the flames. A team may then attempt to cap the leaking gas.

October 1988, around 400,000 hectares – almost half the park's total area – had been burnt.



Blow out

The moment every oilman fears is when the drill bit of a rig unexpectedly breaks through into an underground reservoir of high-pressure gas. In an instant, the gas forces its way up the drill casing to the surface where it may lead to a 'blow out'. Any spark or naked flame near to the gas then causes it to erupt in a devastating fire that can burn for days or even weeks.

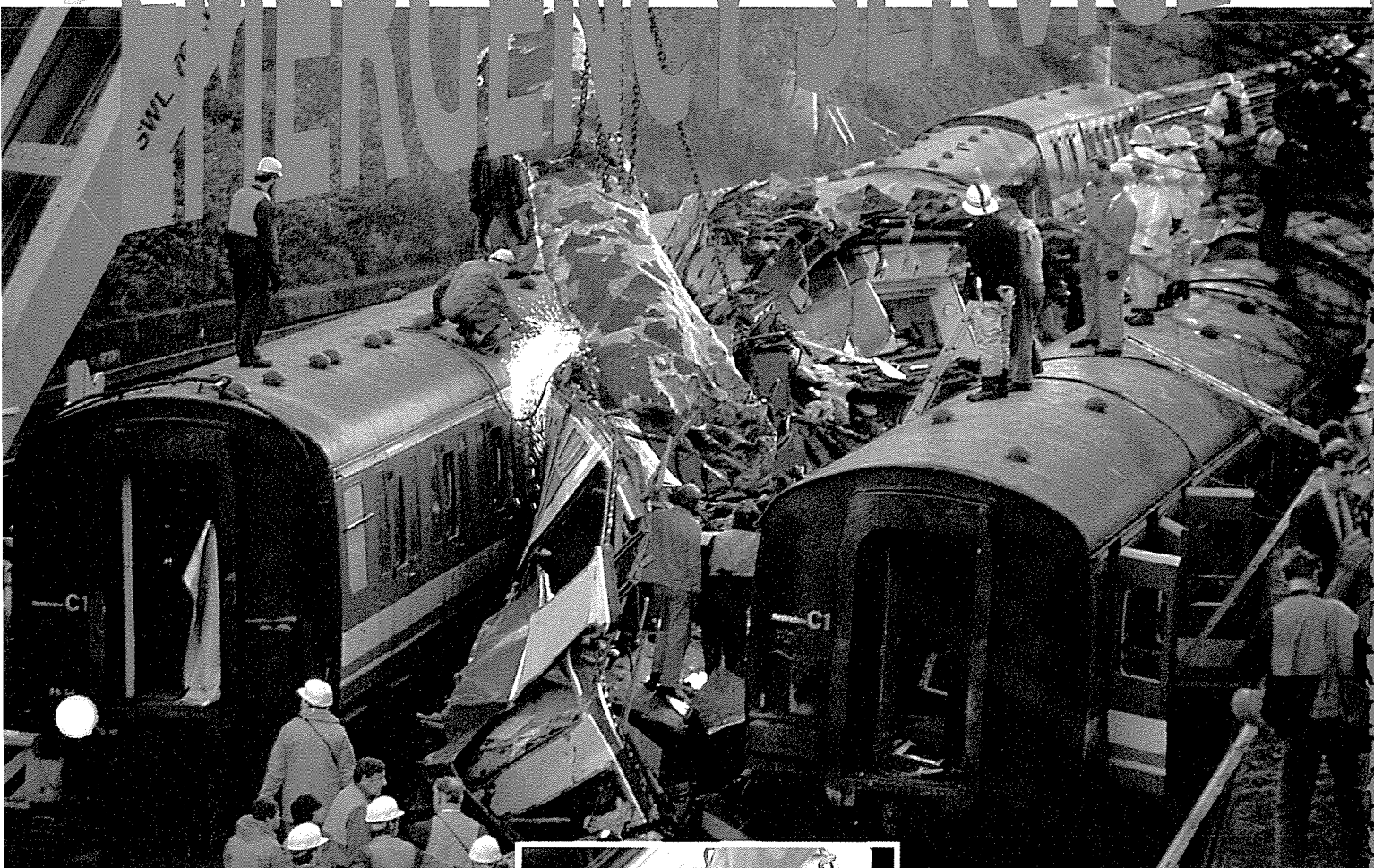
On land, a common way of tackling drill-rig fires is literally to blast away



Paul Raymonde



EMERGENCY SERVICES



TWO CARS HAVE COLLIDED head on. One man is lying on the roadside covered in blood. Several others are trapped in the wreckage, unconscious and badly injured.

Within minutes, a passer-by has phoned the emergency services and given details of the accident and its whereabouts to the control officer at the local ambulance headquarters. From here, radio instructions go out to the ambulances nearest the scene of the accident and the rescue mission begins.

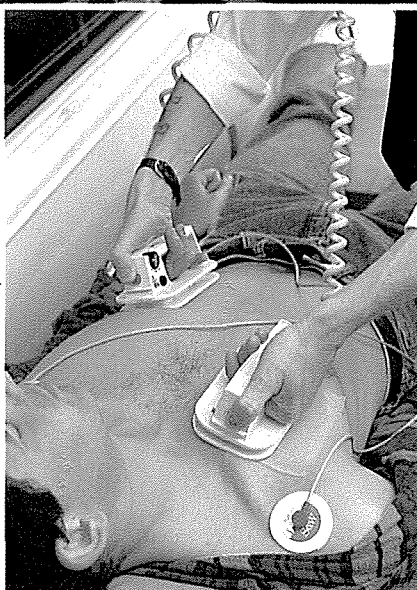
Front line ambulances, used for accidents and emergencies, are packed with essential equipment for reviving patients and keeping them alive on their high-speed journey to hospital. Besides blankets, dressings and stretchers, the ambulances carry:

- suction apparatus to clear breathing passages
- resuscitators to force oxygen into the lungs of a person who has stopped breathing
- splints to support broken limbs
- anaesthetic gas

On arrival at the scene of an

Rex Features Ltd

Adam Hart-Davies/Science Photo Library



accident, the ambulance crew has to assess which of the casualties needs most urgent attention. Anyone who is not breathing, or is having difficulty breathing must be seen to immediately. An aspirator is used to suck blood from the mouth and the passage to the lungs. Then a plastic tube is inserted down the

Cutting equipment was used to reach the injured and clear the track after a rail disaster at Clapham Junction, London, 1988.

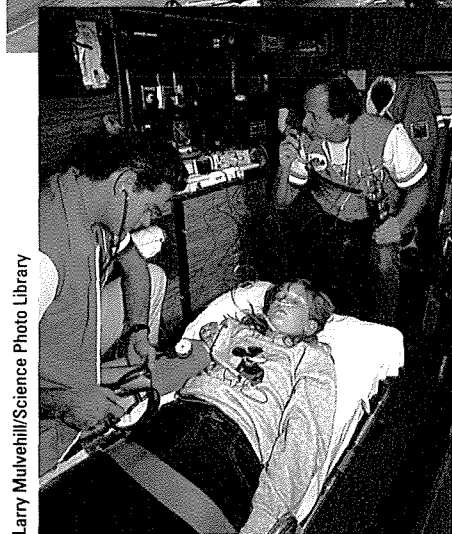
A defibrillator is used to deliver a controlled electric shock to a patient in order to restart his heart when it has failed.

LIFEBOAT EQUIPMENT

Liferafts, inflatable dinghies, floodlights, a loudhailer system, stretchers, life-lines, fire-fighting and oxygen equipment, boathooks, food provisions and parachute flares (that illuminate the area around the lifeboat at night) – all these make up just some of the equipment that a lifeboat carries.

When a ship is stuck on rocks and a lifeboat cannot get alongside it, a breeches buoy is used. A rocket-propelled gun fires a line from the lifeboat to the ship. Then a thicker rope is pulled on board and stretched between the two vessels. The breeches buoy is a seat that is slung beneath the rope, allowing one person at a time to be transferred to the lifeboat.





Larry Mulvehill/Science Photo Library

Communication is essential to ensure the relevant rescue services attend an accident. An ambulance crew (left) often contacts its destination hospital for guidance.

throat to keep the airway open. Finally, an oxygen mask is fitted over the person's face. The next priorities are unconscious casualties and those who are bleeding severely.

Some ambulances have a heart monitoring unit on board. The shape of each pulse appears on a small screen, while a permanent record can be plotted out on a

continuous strip of paper. If a casualty's heart has stopped beating, there will be no pulse. In this case a defibrillator (linked to the monitoring unit) may be used to try to restart their heart.

Shock treatment

The defibrillator consists of two hand-held plastic 'paddles', with metal discs at their base. Applied together, these deliver a momentary electric shock across the casualty's chest. If the first shock fails to start the heart beating, further attempts are made using stronger currents.

If a casualty is losing a lot of blood, there may not be enough fluid left in his or her circulatory system for the heart to continue pumping oxygen-rich blood to essential organs, such as the brain. Donor blood has to be carefully matched to the blood type of the recipient. This can only be done at hospital where supplies of every blood type are held. To keep the casualty alive until then, the ambulance crew



ZEFA

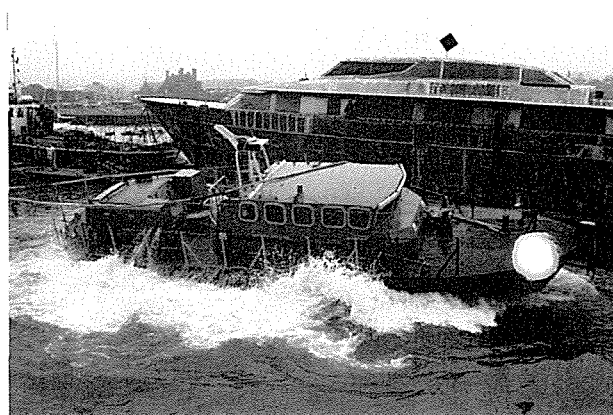
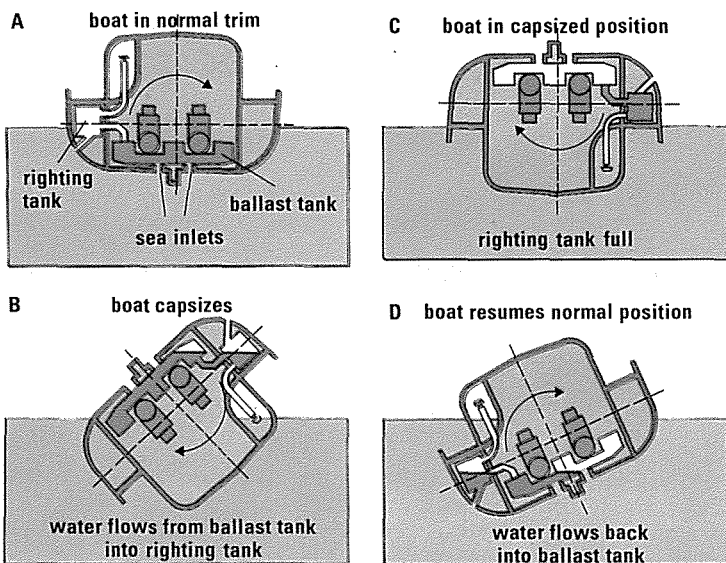
Helicopters are often invaluable when other services are rendered helpless – for searching inaccessible terrain or for lifting people from the sea.

THE SELF-RIGHTING LIFEBOAT

Modern lifeboats are designed to be self-righting. Some – including inshore rescue craft – are fitted with inflatable airbags mounted on the stern of the craft. The bags are slightly off-centre so that the boat is righted immediately if it is knocked over. Others are fitted with the Oakley self-righting system.

The Oakley system consists of a ballast tank in the bottom of the hull that is filled with water. A second tank – the

righting tank – is mounted on the port (left) side. As a boat capsizes water rushes from the ballast tank in to the righting tank. The weight of the water either checks the turning movement or turns the boat through 360° back to upright position. Then the water flows back from the righting tank to the ballast tank. The whole operation takes 5–8 seconds, and is controlled by a system of specially designed valves.



RNLI

Swiss mountain rescuers pull an injured skier from a crevice. Rescue workers – often volunteers – are experienced climbers and skiers familiar with the local area.

Injured skiers and climbers are sometimes unable to be helicopter lifted without ground assistance. They may be unconscious, or buried in snow after an avalanche.

rescue team must try to reach the casualty on foot. Someone who is not badly hurt may be carried down steep rocks on a rescuer's back using a special harness called a Tragsitz. Otherwise, the injured person is tied to a stretcher and lowered by rope. Most stretchers consist of a strong, lightweight metal frame set on ski runners.

Animal sense

When people are missing in the mountains, search dogs are especially valuable. These are trained to follow human scent trails and will find articles like rucksacks and pieces of clothing. In partnership with its handler, one dog may be more effective than twenty human searchers, particularly at night or in bad weather.

Large search and rescue operations, such as that following an air crash, may also involve helicopters, supply lorries and 4 wheel drive vehicles equipped as ambulances and communications centres.

In coastal areas, the coast-guard forms a fourth emergency service, in addition to those of police, fire and ambulance.

Mayday

Coast-guard rescue centres are manned 24 hours a day. Channel 16 VHF – used internationally for distress calls – is monitored continuously. Local frequencies used for communicating with ships, aircraft, lifeboats and coast-guard vessels will also be monitored.

Planning a search and rescue at sea is more complicated than on land because tides, currents, and

administers a kind of artificial 'blood'. This is a clear liquid that substitutes, temporarily, for natural plasma – the colourless, watery substance that blood cells float in.

Mountain rescue

When people get injured or lost in remote highland areas, the nearest mountain-rescue team is alerted. The team consists of volunteers of expert climbers with a good knowledge of the local mountains.

Once the team leader has been briefed by the police, he or she contacts the rest of the team by phone or radio bleeper. The team members assemble their equipment, which includes ropes, climbing gear, stretchers and first-aid

Sniffer dogs, with their highly developed senses of smell and hearing, are valuable aids in searching for people buried by snow or rubble. This one searches the rubble in the aftermath of the Mexican earthquake in 1985.

materials, then head towards an arranged meeting place. Meanwhile, a police car drives as close as possible to the scene of the accident to act as a communications centre and base for operations. All mountain-rescue teams carry portable two-way VHF radios for keeping in touch with the control base.

If someone is injured, the team leader has to decide on the best method of rescue. In some cases, a helicopter may be called for. But if weather is bad or visibility poor, the

wind have to be taken into account. For this reason, computers are being used more and more in coast-guard operations. Given a vessel's last reported position together with prevailing sea and weather conditions, a computer can quickly isolate the area to be searched.

Fax machines are used by the coast guard to send and receive copies of weather charts, maps (showing, for example, the location of an oil spill), and ship cargo details. Computerized telex, by which mes-

ZEFA

Gamma/Frank Spooner Pictures



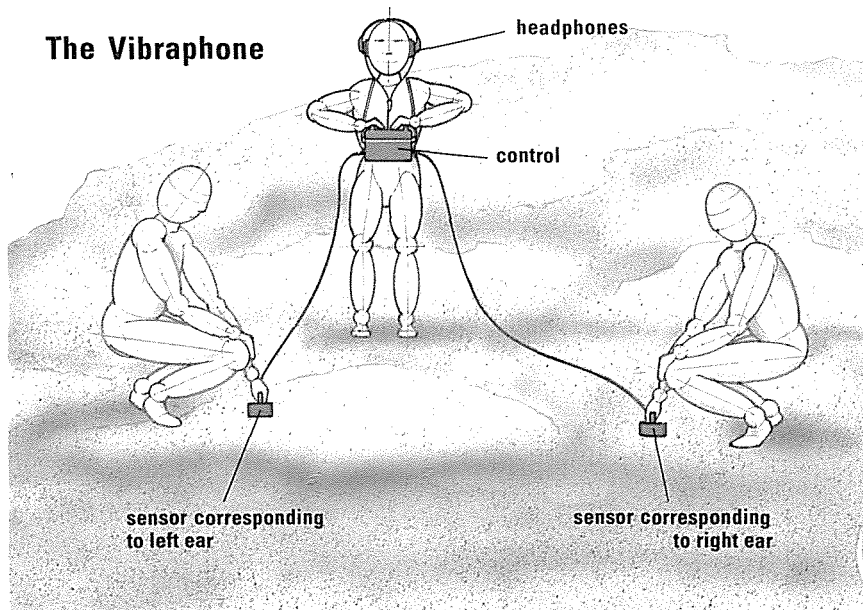
Paul Raymonde



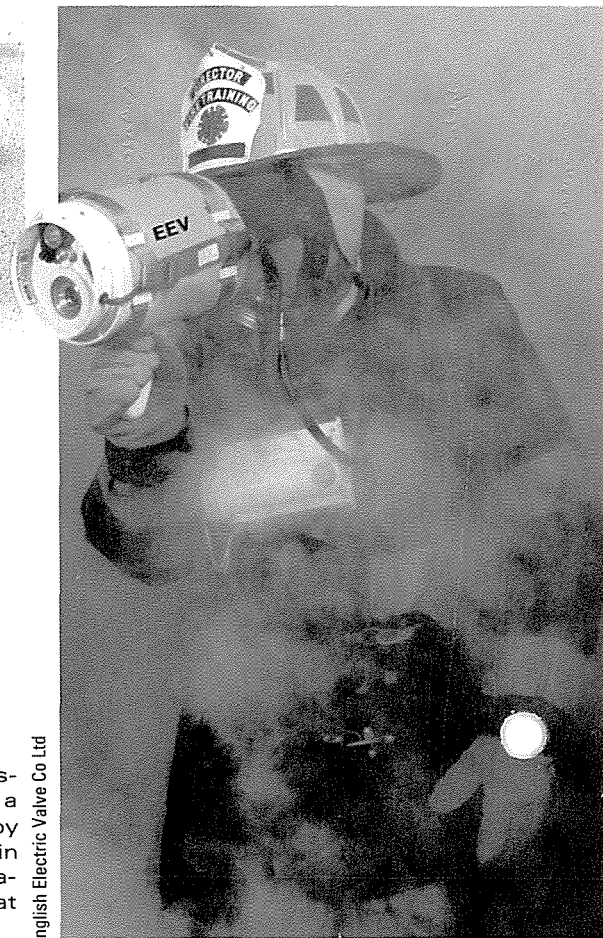
Rex Features Ltd



The Vibraphone



Thermal cameras have lenses made of tiny cells that are sensitive to heat changes of 0.5°C. They 'see' heat pictures through smoke and flame and can pinpoint casualties, or the source of a fire, and relay the information via electronic signals back to a control centre.



English Electric Valve Co Ltd

John Houghton

sages can be sent automatically, has also recently replaced ordinary telex.

Most coast-guard rescue centres are equipped with a VHF direction finder for locating a vessel from its radio signal. Two radio masts at different points along the coast provide cross-references, enabling a ship's position to be calculated.

If a vessel is far from shore, ships and coast-guard stations exchange clear messages via orbiting satellites. In 1979, an international organization known as *Inmarsat* was set up to manage a worldwide system of satellites for maritime communications. A message beamed up to one of these satellites from a ship at sea is relayed to a large dish aerial on land known as an earth station where it enters the tele-

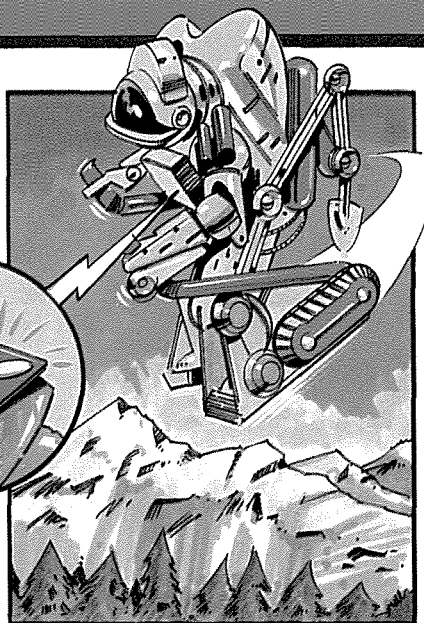
Sound vibrations transmitted through solids are detected by a vibraphone, which is used to find people who are buried alive. Sensors pick up and amplify (make louder) underground noises such as knocking, scratching or breathing. Each amplifier is connected to one headphone and noises also register on the control panel. The operator is able to direct his helpers to the spot because the sensor nearer the casualty will pick up a louder signal.

phone or telex network. The message can then be quickly routed to a coast-guard station that replies by the same system. If a ship is in difficulty it can transmit an automatic distress signal, via satellite, at the touch of a button.

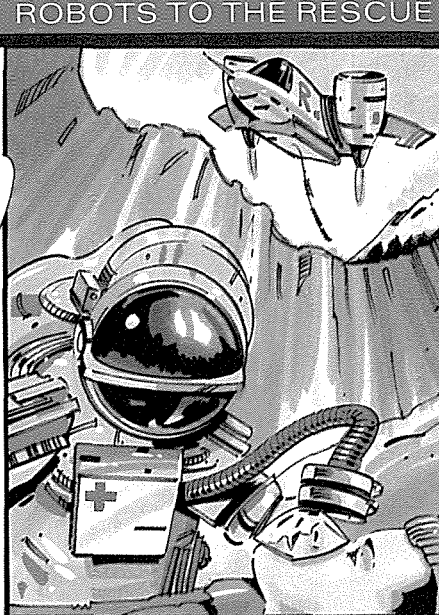
INTO THE FUTURE



▲ Skiers of the future will carry tiny transmitters that will be automatically activated in an emergency – such as being buried in snow after an avalanche.



▲ A robot searcher, launched just after the avalanche, will fly to the distress signal given out by the transmitter, then carefully dig its way down to the trapped skier.



▲ Having found the skier, the robot will administer any emergency treatment that may be necessary while calling for the airborne rescue services.

Joe Lawrence

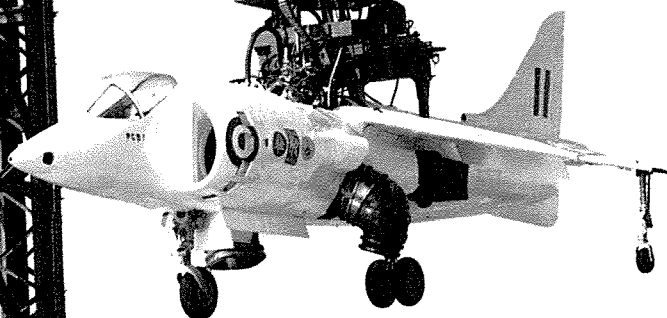
ROBOTS TO THE RESCUE



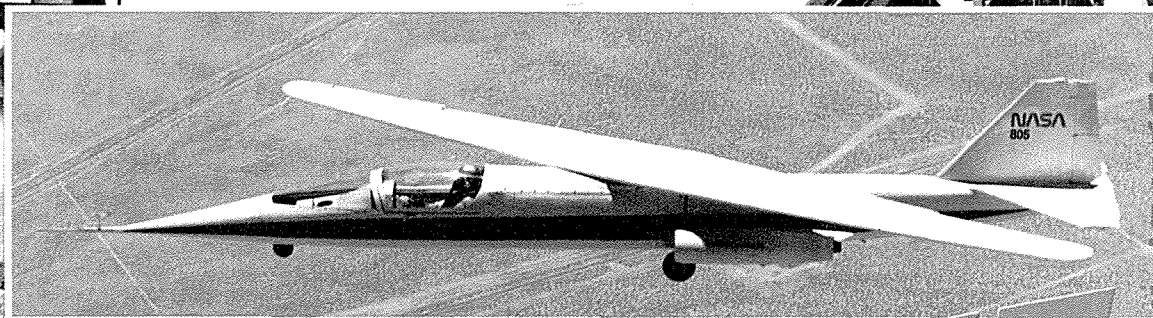
JUMP-JETS

STOL AIRCRAFT

SWING WINGS



The Harrier jump-jet, here on a rig to test the thrust of its Rolls-Royce Pegasus engine, has the unique ability to take off and land vertically. NASA's AD-1 (inset below) features a pivoting wing that reduces drag, so increasing speed and range.



VERTICAL

TAKE-OFF

AIRCRAFT THAT CAN SWIVEL their engines or alter the shape of their wings have proven themselves to be formidable fighting machines. They offer the advantages of several ordinary planes.

Jump-jets, or vertical take-off and landing (VTOL) planes, combine the manoeuvrability of a helicopter with the speed of a high-performance jet. The best-known and most successful is the British Aerospace Harrier.

Air, taken in by the Harrier's single Rolls-Royce Pegasus engine, is compressed and then blasted out of four nozzles, two on each side of the aircraft. For take-off and landing, these

nozzles are angled straight down to provide vertical thrust. Small air jets called 'puffers', at the tips of the wings and at each end of the fuselage, allow the pilot to stabilize the Harrier when it is hovering. Once the plane is off the ground, the nozzles can be gradually swivelled back to push the Harrier forward up to a maximum speed of over 1,160 km/h, or Mach 0.95.

VIFFing

While other fighters may be faster, the Harrier more than makes up for this by a technique called VIFFing (vectoring in forward flight). If another plane is chasing him during a

dog-fight, the Harrier pilot can suddenly rotate the side nozzles from the fully back position through 180 degrees. This slows the jump-jet in mid-air far more rapidly than conventional air-brakes could, so that the pursuing plane overshoots. The Harrier pilot can then quickly turn the nozzles back through 180 degrees to give maximum forward thrust again and get on the tail of his enemy.

Short Take-Off and Landing (STOL) aircraft, by contrast with VTOLs, do need a runway — but a much shorter one than for a normal plane. This allows them, for example, to fly right into the heart of a city or mountainous terrain, where a long

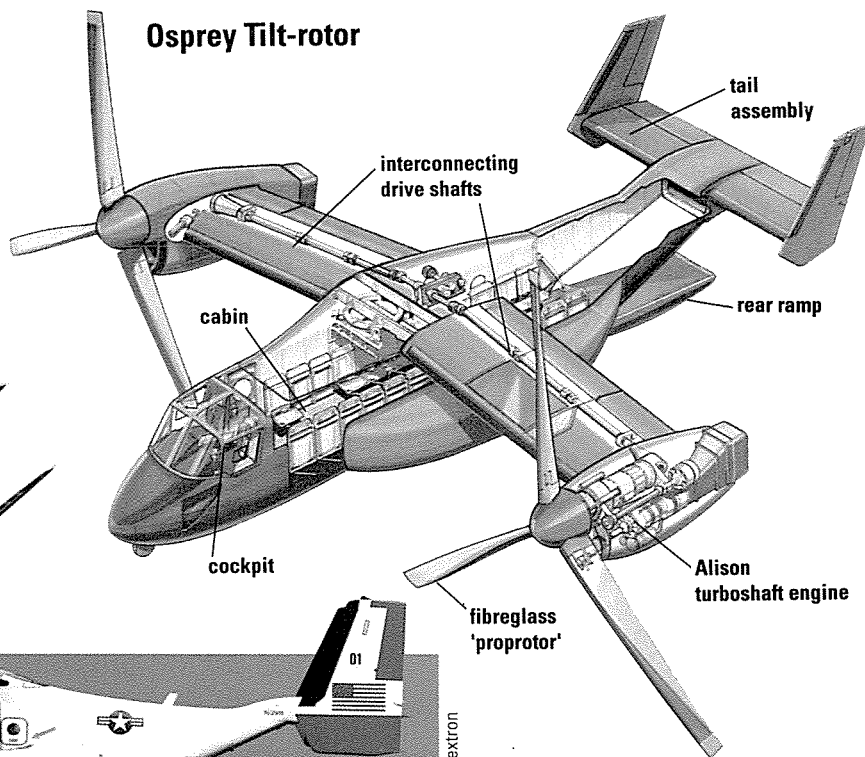


landing strip would be extremely difficult to build.

STOL aircraft work by generating extra lift at low speeds. The Boeing C-14 transport plane, for instance, has its engines mounted on top and in front of the wings. This allows it to make use of a property known as USB, or Upper Surface Blowing.

Coanda effect

The C-14's wing flaps curve down behind the wings' trailing edges. This causes the jet exhaust gas blowing over the wings' upper surface to 'stick' to the flaps and so be directed almost straight down creating a powerful lift. To see this phenomenon, known as the Coanda effect, in action, simply hold the back of a spoon



The V-22 Osprey features a tilt-rotor that allows it to hover like a helicopter and cruise in normal flight at 610 km/h.

Bell Helicopter Textron

Bell Helicopter Textron

Bell Helicopter Textron

under a running tap and notice the way the water closely follows the curvature of the spoon.

An alternative approach to STOL is that used in the American Bell XV-15 research aircraft. Known as a tilt-rotor, this employs propellers, instead of jets, mounted on engines that swivel at the wingtips to provide horizontal or vertical thrust.

Increased lift

Wings that stick straight out give good lift at low speeds, while swept-back wings are more efficient for supersonic flight. With this in mind, a number of fighter planes have been developed that have swing-wings, which can be gradually angled back as the aircraft gathers speed.

The two-seater Panavia Tornado, which entered service in Europe in 1982, has wings that are connected to a rigid box inside the fuselage. Hydraulic jacks allow them to be

moved backwards or forwards. At take-off, the Tornado's wings are spread out wide for maximum lift so that the plane can use a fairly short runway, despite its heavy load of missiles and full fuel tanks.

Reducing drag

As the plane flies faster, however, the increasing flow of air around the wings generates more and more lift. The pilot can then operate the swing-wing control, progressively sweeping back the wings to reduce drag as he throttles up to a top speed of 2,333 km/h, or Mach 1.9.

A different and much stranger looking kind of swing-wing plane, known as the AD-1, has been tested by NASA. This has a single wing that pivots like a scissor blade over 60°. Again, this reduces drag at high speed but is both lighter and simpler because there is only one swivel point instead of two.

Cockpit controls in the Osprey change automatically from hovering to forward flight as the 'proprotor' swivels.

Just amazing!

NIFTY MOVER

THE BRITISH AEROSPACE HARRIER JUMP-JET IS THE ONLY AEROPLANE IN THE WORLD THAT CAN TRAVEL BOTH FORWARDS, AT SUPERSONIC SPEEDS, AND BACKWARDS, AT 80 KM/H.



Paul Raymond



The wings of the Tornado extend to provide the necessary lift to take off with a full payload of weapons and fuel.

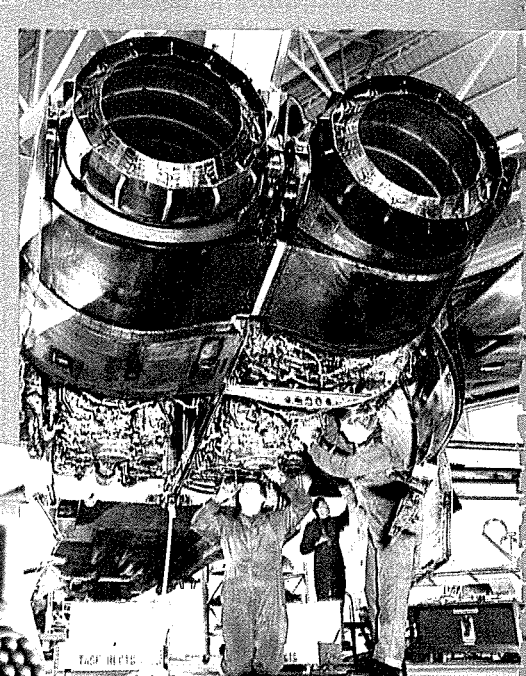
British Aerospace



AIR FORCE
 AIR FORCE
 AIR FORCE

AERIAL

WARFARE



RAF technician working on post-flight check of a Soviet MiG-25 after a day's training.

The AH-64 Apache ground attack helicopter, armed with anti-aircraft missiles and a 30mm cannon, is shown in a training exercise at the Sarny airfield.

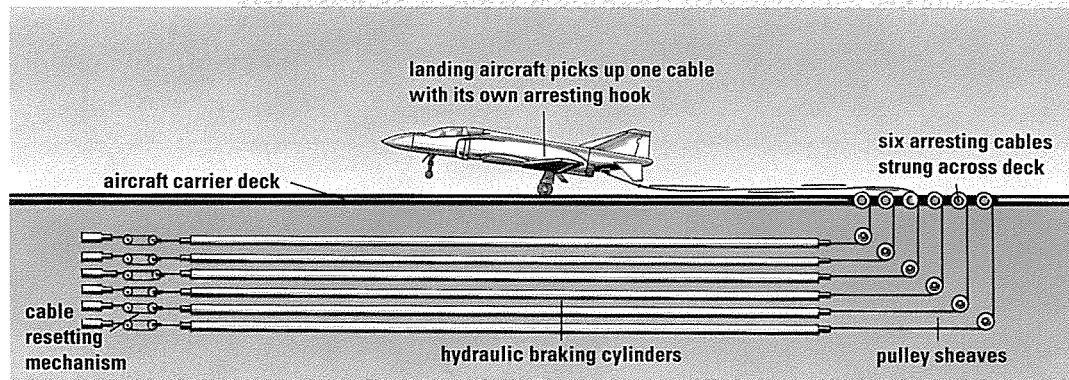
AERIAL WARFARE TODAY takes place at super sonic speeds between aircraft carrying an incredible array of weapons. The first line of defence is a platform which carries the most powerful weapons, made up of fighters and strategic bombers. Each of these consists of a weapons platform (the plane itself) together with the weapons system (missiles, bombs, etc) that it carries. It is obvious from the fact that the only types of military aircraft used for reconnaissance, interception and air refuelling. Finally, modern aerial warfare would be impossible

without support from a sophisticated network of communications, electronic equipment and radar tracking stations situated on the ground.

Interceptors
 Most spectacular in their performance are the interceptors. These are used to engage enemy planes in day, night and in all-weather conditions. Russia's MiG-25, code named Foxbat, for instance, was built to intercept American B-70 Valkyrie supersonic bombers. Although not agile enough to be effective in dogfights, the MiG-25, loaded with 4 heatseeking missiles

can reach the astonishing speed of 2,930 km/h — equivalent to 2.8 times the speed of sound, or Mach (after the scientist Ernst Mach) 2.8. In due course, the Valkyrie programme was cancelled, but the fact that Russia now owned the fastest interceptor plane in the world meant that the US had to have an aircraft that could counter it. Thus it developed the McDonnell Douglas F-15 Eagle which, though slightly slower than the Foxbat, is one of the most fighters ever built. Whereas the role of an interceptor is purely defensive, that of a combat dogfighter is aggressive. This type of

FLOATING AIRFIELDS ON THE OCEANS



John Houghton

Aircraft carriers are mobile airfields from which attacks can be launched on other ships or at targets on land. One of the problems that carrier-based planes face is in taking off or landing since the runway is so short. To help them gain flying speed quickly, the aircraft is attached to a steam-powered catapult. The pilot opens his throttle wide and the aircraft, powered by its own engines

and the catapult, accelerates down the flight deck. At the end of the runway, the aircraft disengages from the catapult mechanism and flies under its own power. To land, the pilot releases an arrester hook from the rear of the plane. This catches a damped wire stretched across the landing strip (above), causing the plane to slow from about 240 km/h to rest in about 60 metres.

The F-15 Eagle, pictured accelerating vertically with a full complement of air-to-air missiles, is one of the most powerful fighters in service.

which is a modified version of the commercial Boeing 707. Using a rotating, saucer-shaped radar scanner on top of its fuselage, the Boeing AWACs can spot even low-flying enemy aircraft over 300 km away. It can, therefore, serve as an airborne command centre to co-ordinate and direct the counter operations of friendly planes.

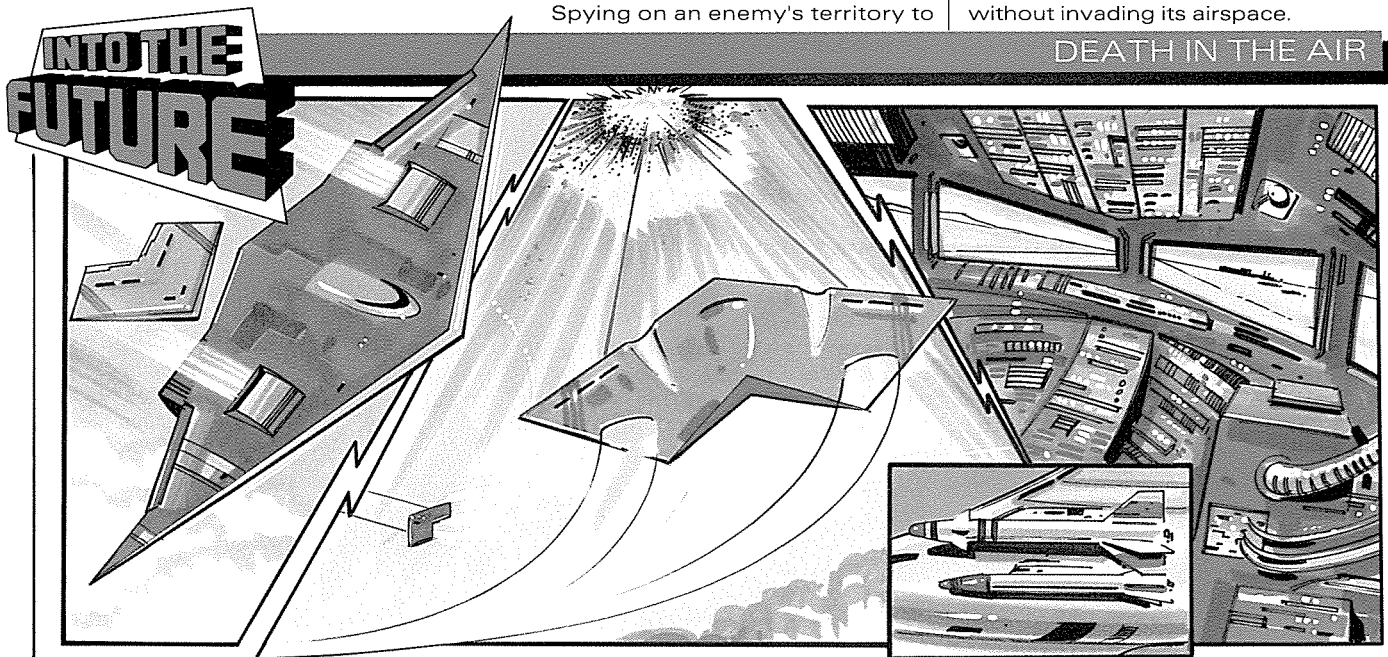
Spying on an enemy's territory to

discover the whereabouts of ground forces and other targets is important before launching an attack. For this task, reconnaissance or 'spy' planes are used, fitted with high-resolution optical and infrared cameras as well as radar equipment.

Reconnaissance

Equipment known as Sideways Looking Airborne Radar, normally carried in a thin oblong box below the fuselage, literally gives a side-on radar view. This means that the spy plane can fly up and down friendly territory, watching the enemy without invading its airspace.

McDonnell Douglas



Joe Lawrence

▲ Most military aircraft will have angular shapes, like Lockheed's F117 Stealth fighter, designed to confuse or even be invisible to enemy radar.

▲ The planes' weaponry will include hypervelocity missiles (HVMs), guided from the launch aircraft by laser and capable of speeds of Mach 4.5.

▲ Eventually, expensive-to-train and non-expendable human pilots may no longer be necessary as 'intelligent' computers and robots take the controls.



Q JET DESIGN

Q G FORCE

Q THE SYNCRO PAIR

CIRCUITS

Richard Cooke

Designed as an advanced trainer and ground-attack aircraft, the 12-metre-long Hawk is powered by a single Rolls-Royce Adour turbofan engine. This can propel the plane to a speed of 1,040 km/h (Mach 0.88) in level flight or 1,420 km/h (Mach 1.2) in a shallow dive, and to a maximum altitude of 15,240 metres. More importantly, the Hawk has all the essential features of a true aerobatic machine.

Modern aerobatic teams around the world often use jet trainers as their display aircraft. The reason is that these planes are purpose-built to

AERIAL ACROBATICS AND formation flying push both men and machines to their very limits. When the RAF's display team the Red Arrows performs, the aircraft may be only a wingspan apart while flying at speeds of up to 600 km/h. Only split-second timing stands between a perfectly executed stunt and disaster.

One of the first tasks of a Red Arrows newcomer is to become totally familiar with the team's high-performance jet — the British Aerospace Hawk.

The Red Arrows' Parasol Break is just one of the team's many formations. The display takes 20 minutes and requires 6km visibility.

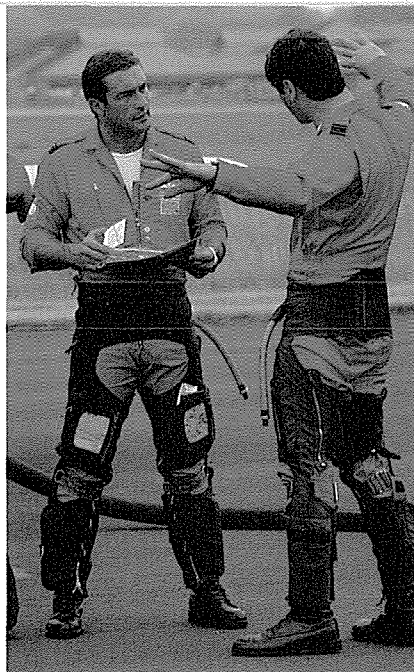


be responsive, agile and predictable in flight. The Hawk, for example, is very difficult to put into a spin by mistake. Only when the pilot throws the rudder fully over to one side will the plane spin at all and even then it will recover after a single turn when the controls are centralized.

Tony Stone Photo Library, London

Power-packed

Another requirement is that the plane should stand up to sudden sharp changes in speed and direction. It must be manoeuvrable yet rugged, and able to handle the differing degrees of G force. A force of 1G is the equivalent of gravity. A simple, 'human-engineered' cockpit with well laid out controls and a bubble



Richard Cooke

canopy for maximum all-round vision are also important to the display team pilot.

The nine Red Arrows pilots are usually posted to the team for three years before returning to normal duty or flight instruction. Selection is based not only on flying skill, but on the pilot's ability to get on well as part of a tightly knit group.

Blood-rush

During a loop-the-loop and similar manoeuvres, an aerobatic plane and its pilot experience up to 7 G, or a force seven times stronger than that of normal gravity. Under these circumstances, the blood in a pilot's body tends to rush downwards away from his brain and there is a risk of him blacking out. To prevent this, all high-performance jet fliers wear anti-G suits. As the aircraft goes into a turn, the anti-G suit inflates tightly around the legs and stomach to prevent too much blood draining from the head.

Smoke trails

One of the most spectacular sights in formation flying is when the aircraft leave long curving trails of coloured smoke left in their wake. These are produced by smoke pods (originally designed in the case of the hawk, to house a 30mm Aden gun) situated beneath the plane's fuselage. The

Pilots experience massive amounts of G force during acrobatic displays. This is caused by the plane's high acceleration. To reduce the risk of black-out, Red Arrow pilots wear anti-G suits (above) which prevent the blood supply draining from the brain.

Tony Stone Photo Library, London

DEADLY DISPLAYS

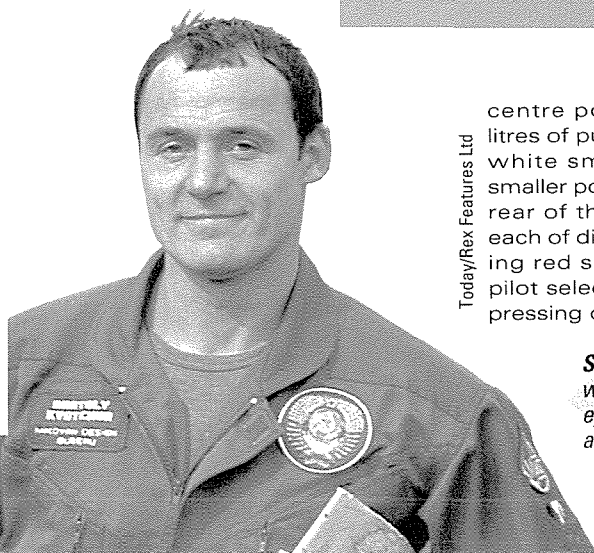


Quadrant/Flight

Soviet pilot Anatoli Kvotchur narrowly escaped death at the Paris Air Show in June 1989, when the right engine of his fighter burst into flames. Kvotchur was forced to eject at an altitude of just 150 metres.

At the 1973 Paris Air Show, 15 people were killed and 28 injured when the Russian-designed Tupolev — or 'Concordski' — crashed after stalling during a steep climb. In 1988 a member of the 10-strong Italian *Frecce Tricolori* team touched the wing of another plane during a display at Ramstein, West Germany. Three jets crashed into the crowd, killing 47 people.

The Blue Angels are the USA's equivalent of the Red Arrows. Like the Arrows, they fly a specially adapted fighter — the F-A 18. Designed for both defence and attack purposes, the F-A 18 has a top speed of 1,915 km/h.



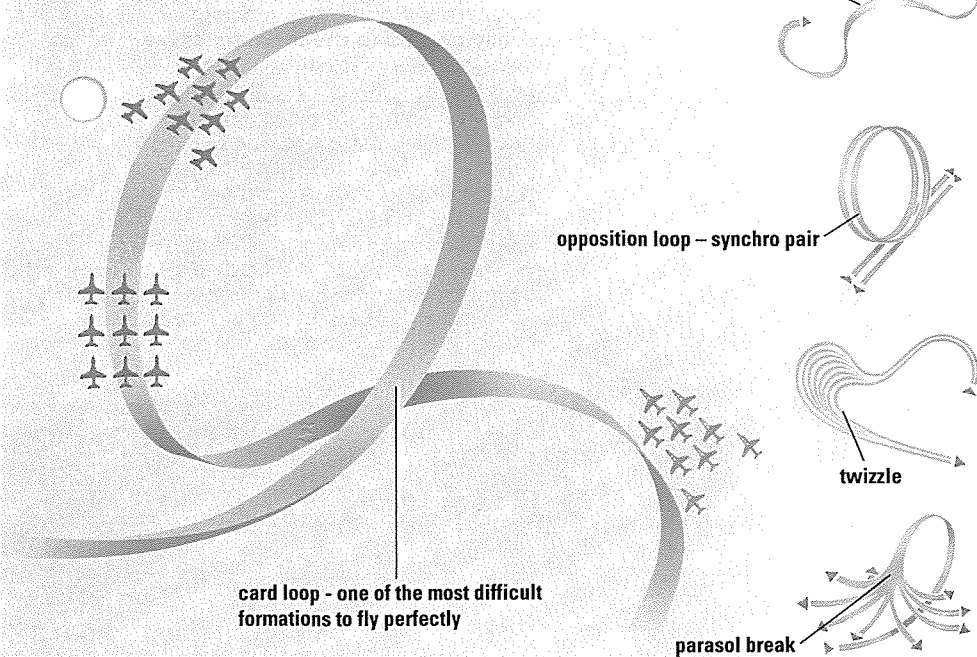
Today/Rex Features Ltd

centre pod on a Hawk holds 227 litres of pure diesel fuel which makes white smoke when burned. Two smaller pods situated to the front and rear of the fuselage carry 45 litres each of diesel/dye mix — one for making red smoke, the other blue. The pilot selects the colour he wants by pressing one of three buttons on top

Soviet pilot Anatoli Kvotchur withstood up to 20 G when he ejected from his Mig-28 fighter at the Paris Air Show.



The Red Arrows' Repertoire



To loop the loop, a pilot has to gain sufficient speed and then pull back on the controls to bring the plane's nose sharply up. At this point, the pilot experiences a dramatic rise in G force – up to 3 or 4 Gs.

of the control column in the cockpit.

In an emergency, the pilot can pull on a handle to eject out of his plane. The canopy covering the cockpit has a continuous loop of narrow lead tubing built in that contains an explosive powder. Two detonators go off as soon as the ejection handle is

developed their own repertoire of formations and aerobatic stunts that they vary slightly from year to year. For instance, during the Red Arrows' full 20 minute programme more than a dozen different group formations are flown. Two aircraft, known as the Synchro Pair, also perform dual stunts.



Richard Cooke

released. These ignite the powder which then shatters the canopy. Less than a fifth of a second later, the pilot is shot out of the aircraft on his rocket-powered ejection seat. The pressure on the pilot reaches 20 G. Tall pilots, especially, risk smashing their knees on the way out or suffering whiplash as their heads are jerked down into their laps.

World-famous flying teams such as the British Red Arrows, the Italian *Frecce Tricolori* and the United States Navy's Blue Angels have each

Gamma/Frank Spooner Pictures



An engineer fills a Hawk's tanks with red dye. Frecce Tricolori (below) have green, red and white smoke trails – the colours of the Italian flag.

Smoke trails are also used to create a dramatic effect during parachute displays. Dye canisters are strapped to the parachutists' legs.

John Carty

Tony Stone Photo Library, London





WEIGHT-WATCHERS

Every astronaut's training programme involves preparation for weightlessness. The trainee crew of a space shuttle are taken up in a high-altitude aircraft, which dives along specially calculated curving paths. For up to a minute, the astronauts experience conditions that are close to zero gravity. They float around, bouncing off the plane's well-padded interior. Astronauts are also trained in centrifuges — machines that revolve at very high speed, which subject them to high levels of G force.

Allsport

Before the day of the display, the pilot leading the Synchro Pair draws up a map of the site where the team will be performing. His task is to mark out any reference headings the Synchro Pair will use. He also marks the datum — a fixed central point over the spectators, around which the whole display will be orientated. Copies of this map are then sent to the team leader and to two pilots, known as Navigation Officers, whose job is to work out the routes and timings so that the Red Arrows arrive over the crowd at exactly the right moment.

The team leader, whose aircraft is always at the front and centre of the

Free-fall
parachute displays can be just as spectacular as formation flying. The record for the largest free-fall formation is held by the 144 American parachutists who, on 11 July 1988, jumped from a height of 4,876 metres and formed a diamond pattern which they held for 8.8 seconds.



ONE-MAN JET PACKS



Gamma/Frank Spooner Pictures

The 1984 Los Angeles Olympics opened with a spectacular ceremony that featured a demonstration of the Bell Jet Flying Belt. This is a back-pack powered by a mini jet engine that propels the pilot vertically and horizontally through the air. The jet engine provides a maximum upward thrust of 195 kg. The US Department of Defense and Advanced Research gave the Bell Aerospace Company a \$3 million contract to develop the the back-pack.

group, calls out brief commands over the radio to synchronize the display. A pattern called Diamond Nine is the basic one from which the Red Arrows develop all of their other formations. All nine aircraft join in formations with names such as Feathered Arrow (familiarily known as 'Fred' by members of the team), Corkscrew, Big-T Leader's Benefit, Swan, Vixen Break, Twizzle, and Parasol Break. At other times the Synchro Pair break away to do their own breath-taking crosses.



Warning sign

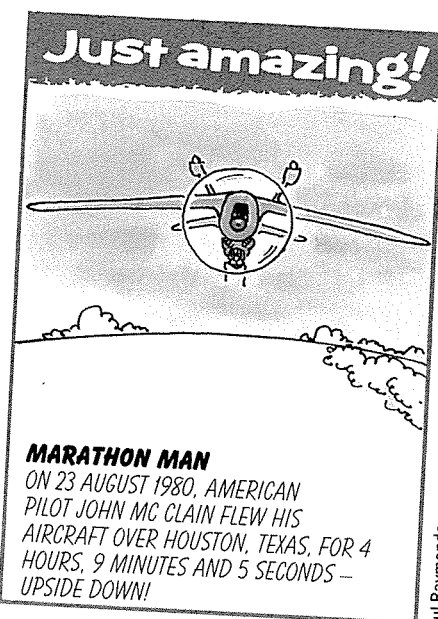
With commands like 'Smoke On', 'Pulling Up', and 'Coming Left' the leader warns other team members of the next manoeuvre. He ensures that his own plane is properly orientated with respect to the agreed datum and is moving at the right speed before calling on the rest of the team to fall in behind. Because the physical demands on each plane vary greatly according to the position it flies in, the aircraft are given different numbers each year to make sure they wear at an even rate.



Weather worries

Weather conditions play a crucial part in aerobatics and formation displays. The Red Arrows, for instance, only fly their full programme, includ-

ing loops and rolls, if the cloud base is no lower than 1,500 metres and visibility is good. If clouds extend down to 800 metres, the team does its spectacular rolls but no high loops. With a cloud base down to 300 metres, the team reverts to its 'flat display', making a series of passes above the crowd.



Paul Raymonde

Microlights can carry no more than two people. Their weight – excluding fuel or passengers – must not exceed 150 kg.

SKYHOOK

Tony Stone/Photo Library, London

Vandystadt/Alisport

MICROLIGHTS

FOR THOSE WHO CANNOT afford a private jet, microlights offer seat-of-the-pants flying at very low cost. Capable of carrying one or two people, they can be bought ready-made or assembled from kits by any capable mechanic.

Keeping down cost and weight are two key factors in microlight design. Generally, the wing is like that of a hang-glider – a triangular-shaped sheet of nylon stretched across an aluminium frame. Below this the pilot sits in a tiny, open cockpit. Some microlights also have room for a single passenger.

A typical microlight is powered by a two-stroke, 250-350 cc, petrol-driven engine, such as that used in a

lawn-mower. The engine may be front- or rear-mounted and is connected to a propeller that drives the craft through the air. A fuel tank with a capacity of about 20 litres provides roughly one hour's flying time, during which the plane may cover 50 km.

Flying for fun

Microlights were developed by hang-gliding enthusiasts, who found the limited availability of sites a major drawback. Hang-gliders can only take off on rising currents of air – usually in hilly areas. This means that pilots often have to travel long distances to find a suitable location. By fitting small engines, a hang-glider could be operated from flat ground.

Since most people who fly for fun

are not experienced pilots, microlights must be both easy to handle and relatively safe.

The controls are kept as simple as possible, in many cases just consisting of a throttle, a lever connected by cable to the wing, and a bar joined by another cable to the rudder. Pushing the lever backwards or forwards alters the angle of the wing to change altitude, while twisting the rudder bar left or right with the feet steers the microlight.

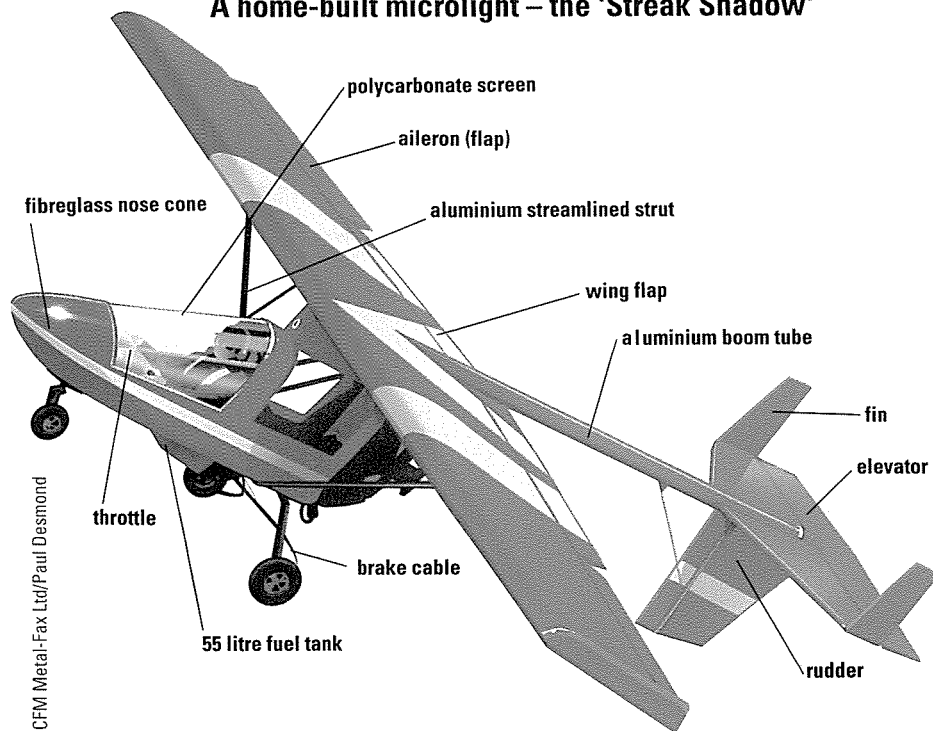
No escape

Safety is of vital concern in microlights because, in an emergency, the pilot has no way of escape. Although some microlights reach an altitude of 4,000 metres, most only fly at a

The World altitude record is held by Australian Eric Winton, who in 1989 flew his microlight to a height of 9,189 metres.



A home-built microlight – the 'Streak Shadow'



CFM Metal-Fax Ltd/Paul Desmond

few hundred metres. Attempting a parachute jump from this height would be suicide.

Microlights are designed so that their stalling speed is as low as 30 km per hour. Normal cruising speed is in the range 45-60 km/h with a top speed of up to 80 km/h, though high-powered models may fly at least twice as fast as this. A microlight's take-off run can be less than 50 metres and the climb rate averages 200 metres per minute.

Crash course

Microlight enthusiasts face the same kind of danger as, for instance, ski jumpers do. If something goes wrong while taking off or landing, the microlight pilot stands to collide with the ground with little indeed to protect him.

Most microlights have very good positive stability. This means that they recover quickly from a minor piloting error or light turbulence in the air. They are also highly manoeuvrable and easy to pull out of a stall. Even if the engine cuts out, the pilot can simply glide down to land in the nearest clear area. Consequently,

The 'Streak Shadow', a more sophisticated microlight, can cruise for up to 640km at a speed of 160 km/h.

microlights have as good a safety record as commercial aircraft.

But accidents do happen. Microlights can be seriously affected by strong winds because they fly at such low altitudes. Using unprepared landing strips can also cause problems. How serious these accidents are depends on the speed of collision and the weight of the aircraft. A crash helmet and safety harness afford some protection to the pilot, while the forward part of the plane is usually designed to absorb at least some of the impact of a crash.

Mini helicopters

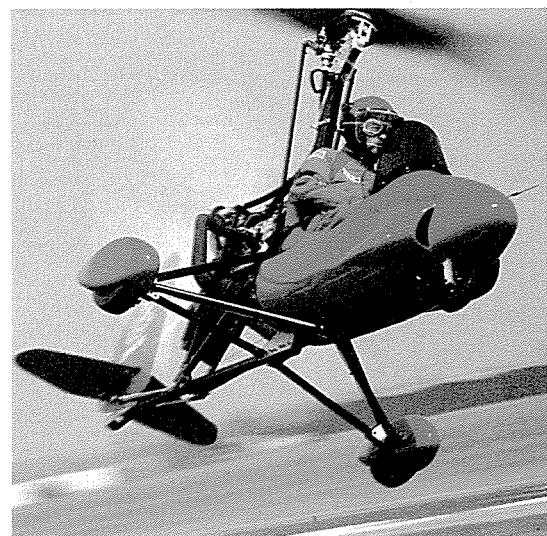
Just as the microlight is the ultimate in small planes, so the autogyro is the last word in miniature helicopters. It, too, gets its forward

Remote-controlled microlights are being adapted for military purposes, such as rescuing pilots from behind enemy lines.

007 AUTOGYRO

This mini-helicopter (below) made a spectacular appearance in the James Bond film, *You Only Live Twice*. It was designed and built by retired Wing-Commander Kenneth Wallis. For the film, the craft was fitted out with model forward-mounted machine guns and twin air-to-surface guided missiles.

In 1975, Wallis set a new straight-line distance record for autogyros by flying 874 km. He went on to break the altitude record with 5,644 metres and in 1986 set a new speed record of 194 km/h.



Mike Valente/Fast Lane

power from a tiny engine and propeller. But in place of a flexible wing it has a rotor blade. This rotor turns in the wind as the craft taxis down the runway, giving lift for take-off.

The autogyro's rotor, however, is not powered by the engine. It will only spin and supply lift providing there is sufficient forward motion. As a result, autogyros cannot hover, or land and take off vertically, as conventional helicopters can.

Just amazing!

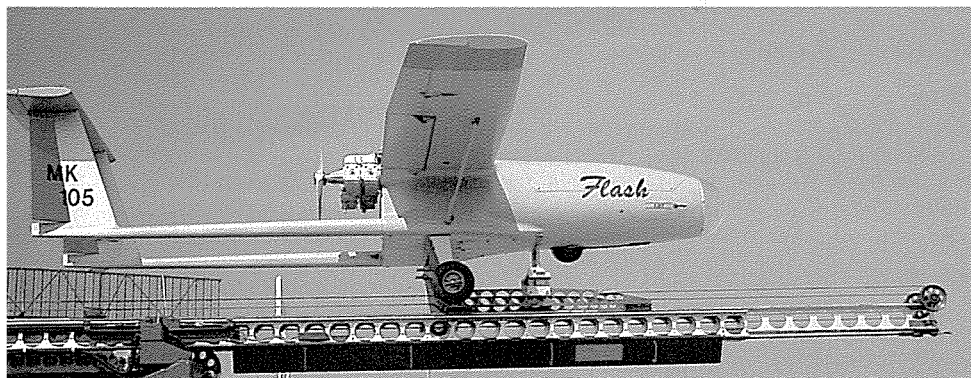
DOT ON THE HORIZON

THE SMALLEST TWIN-ENGINED PLANE IN THE WORLD IS THE CRICKET. IT STANDS JUST 1 METRE HIGH AND WEIGHS LESS THAN ITS PILOT!



Paul Raymonde

Aviation Picture Library

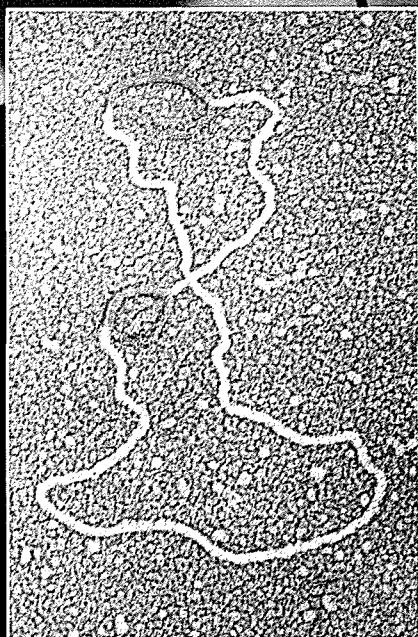


■ X-RAYS

■ ENDOSCOPY

■ GENE MARKERS

MEDICINE NOW



PA McTurk University of Leicester & D Parker SPL

Identifying individual genes on a strand of DNA with coloured dyes in a process known as 'gene mapping' - the first step in finding the cause of disease.

ADVANCES IN MEDICAL science now enable many childless couples to have families of their own, amputees to have replacement limbs, the deaf to regain their hearing and the blind to have their sight restored.

All of these modern miracles are the result of a mass of painstaking research by anonymous workers. Dr Christian Barnard, for example, would not have been able to perform the first human heart transplant without the 'backroom' scientists developing techniques for accurate tissue typing, engineers improving heart/lung machines, organ storage containers and vital monitors to check the condition of the patient during and after the operation.

A research scientist, looking for a cancer gene, uses ultraviolet light while extracting DNA from a solution during a genetic engineering experiment.

Many of these advances have happened very slowly as early, simple techniques and machines have been modified and improved over many years. The need for these advances creates its own pressure for improvement.

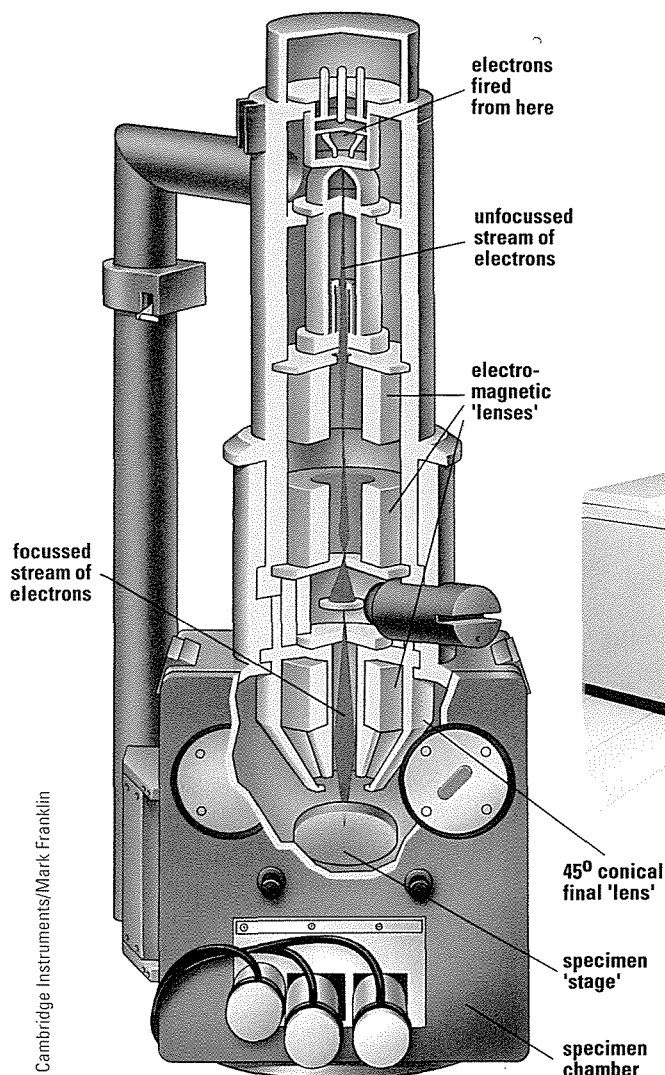
Fibre optics

The endoscope (from endo, meaning inside and scope, meaning to see) is an instrument that uses the fact that light can be conducted along very thin fibres of glass. Fibre optic bundles are bound together with

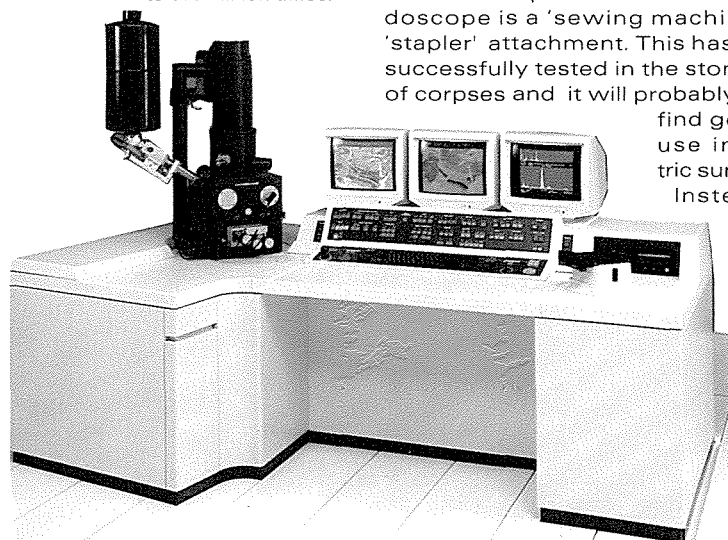
Hank Morgan/Science Photo Library



Scanning Electron Microscope

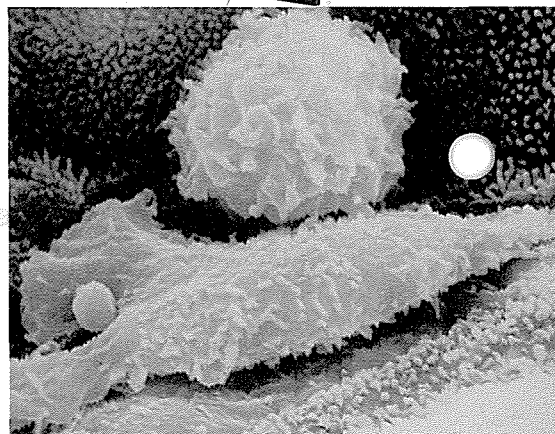


The scanning electron microscope uses a fine beam of electrons that are controlled by magnetic 'lenses' sweeping rapidly back and forth across the specimen to create magnifications of up to 100 million times.



Cambridge Instruments

Magnification times 3,500 reveals two macrophages in a human lung. Normally spherical (top), they elongate and engulf particles of dust, pollen and bacteria (bottom left).



pipes and wires to form an instrument that can be inserted into the body and used to examine the inside of almost any body cavity. The inside of the cavity is illuminated by light passed down one bundle of glass fibres and the surgeon sees through

another set, which is equipped with a strong lens.

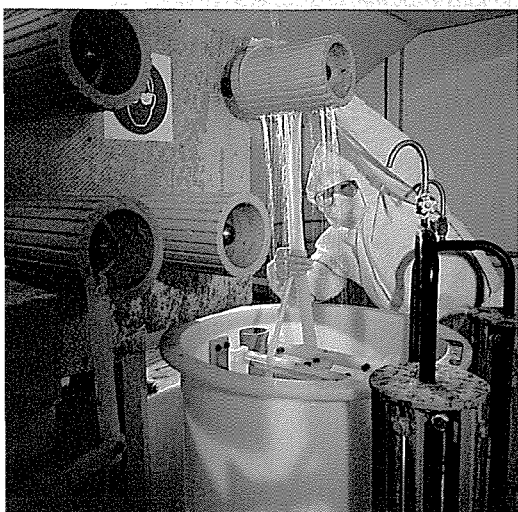
The surgeon controls the endoscope from outside the body using the control wires. Light travelling along the optic bundles relays a picture along the endoscope to a

viewing instrument held in front of the surgeon. The image can also be displayed on a video screen. When he finds a diseased part, the surgeon can operate on it using the control wires to the instruments of the endoscope without having to make a large opening in the patients body.

Surgical stapler

One instrument that has recently been developed for use with an endoscope is a 'sewing machine' or 'stapler' attachment. This has been successfully tested in the stomachs of corpses and it will probably soon find general use in gastric surgery. Instead of

SEAWEED DRESSING FOR WOUNDS



Traditional bandages tend to stick to new tissue and damage it on removal, causing pain, distress and slowing the healing process. But researchers at Courtauld's in Coventry, UK, have discovered how to convert sodium alginate found in brown seaweed harvested off the west coast of Scotland into a special bandage. When this is used to dress a wound, it forms a gel that creates the right degree of moisture for healing. In trials with the new bandage it has been found that leg ulcers and bed sores, two conditions that are very difficult to deal with using normal bandages, healed quickly and easily. When the dressing needs to be changed, it can simply be washed away with a salty solution, leaving the newly grown tissue intact.

cutting open the patient's stomach for operation on, say, a peptic (stomach) ulcer, the endoscope will be passed through the mouth and down into the stomach. Surgical instruments at the end of the endoscope will be used to perform the small operation and the 'sewing machine' or 'stapler' used to stitch up the wound. As a result, the patient will have no major surgery to recover from and no external scars.

Radiation

X-rays have been used for many years to 'see' bones inside the body. This system uses fairly high doses of radiation, so it is inadvisable to have too many X-rays taken. Also, the information given does not include the soft tissues of the body surrounding the bones.

The newer system of Computerized Tomography (CT) also uses X-rays, but delivers a lower dose of radiation. It works by computing how

Dr Arnold Brody/Science Photo Library



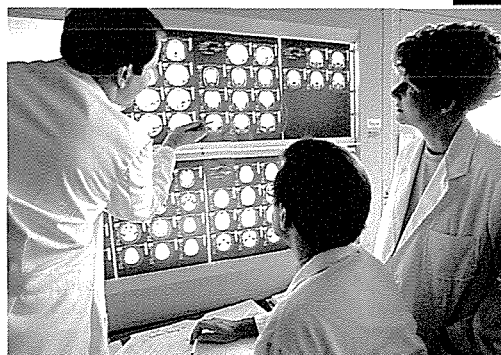
much radiation is absorbed by tissues of differing density. The information from the voxel (the name for the area being scanned) is fed to a computer, which sorts it out and produces an image that can be displayed on a video screen. The picture produced is of bony and surrounding soft tissues.

Body scanner

Magnetic Resonance Imaging (MRI) is also used to view both hard and soft tissues of the body, but it does not use X-rays at all. X-rays are very efficient when looking at the hard bony structures of the body, but they do not show the surrounding soft tissues with any clarity.

In MRI the patient is placed in a powerful magnetic field and exposed to harmless, high-frequency radio waves. The protons in the nuclei of certain atoms, particularly hydrogen atoms, absorb the radio waves and then give out more radio waves when the radio signal is switched off. This method is used to detect abnormal concentrations of atoms such as hydrogen, sodium, potassium and carbon. The signals

The PET scanner produces a detailed image of the brain from a radioisotope that is injected into the body. Brain scans produced by MRI (below), rely on extremely powerful magnets.



are analysed by a computer and displayed as a colour image on a screen. An experienced operator can easily see where a disease is located.

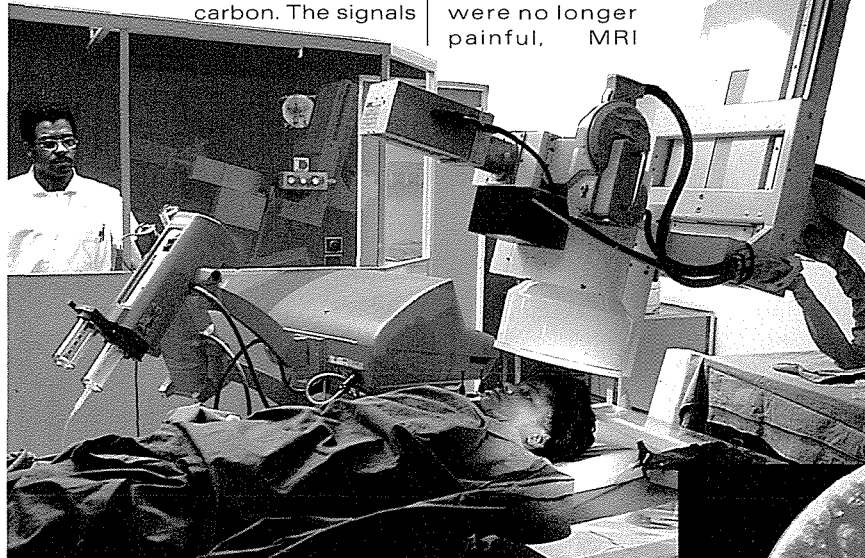
MRI has recently been used to study muscle injury and rates of recovery. It was found that even when injured muscles were no longer painful, MRI

they contract has been known since about 1660 but little or nothing was made of the discovery.

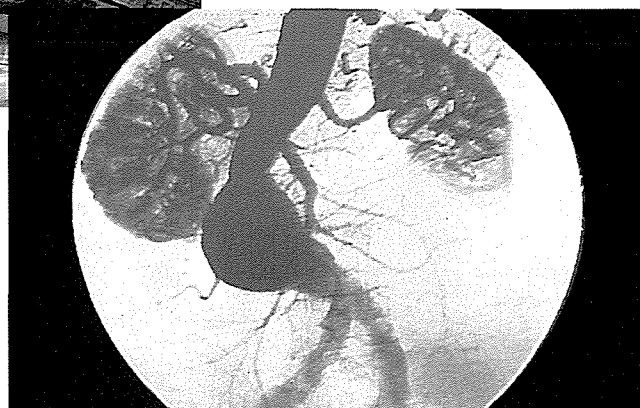
Muscle sounds

In the last few years, researchers have looked at the potential use of this phenomenon. An electronic stethoscope is attached to a body area such as the arm and the sound produced from contracting muscles is fed to an amplifier and computer system known as the Fast-Fourier-Transform Device. This instrument separates the sounds, and signals a paper recorder which gives a printed readout. Using this method, injuries from torn muscles to heart abnormalities could be detected.

Heat is produced by living human tissue. The amount of work performed by the tissue is essentially



Angiography is an X-ray technique that uses an injected dye to visualize blood vessels. This angiograph (right) reveals an aneurysm – a swelling in a stomach artery.



images showed tissue repair continuing for up to three weeks. This could mean that athletes who are apparently cured of an injury should still refrain from heavy training and competition for two to four weeks to allow for complete repair.

The phenomenon of muscle sounds may be used in the near future to study muscle development and repair. The fact that muscles make low frequency noises when

proportional to the heat produced. Injured tissues have a greater blood supply to improve healing and are therefore warmer than surrounding tissues. This phenomenon has been utilized in the production of heat-sensitive films, which contain crystals that change colour with temperature. Forehead thermometers are simple examples of these films.

Large sheets of similar film are used to study temperature change in



Philippe Pailly/Science Photo Library

Paul Raymonde

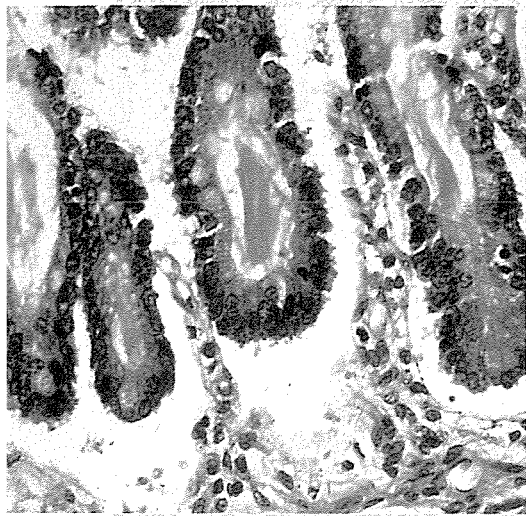
Will & Deni McIntyre/Science Photo Library

Alexander Tsiras/Science Photo Library

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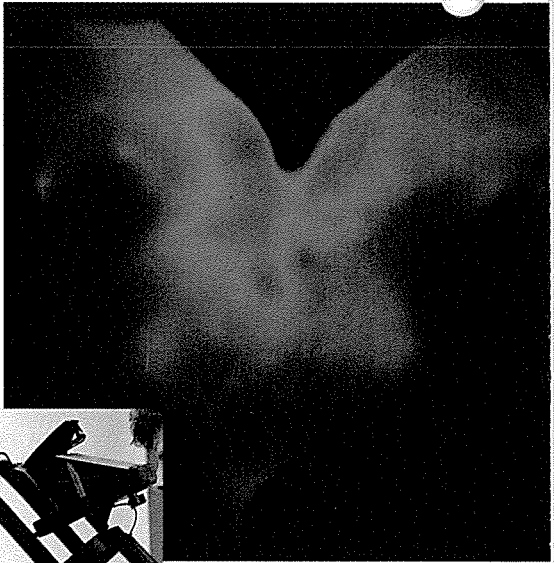
THE SEARCH FOR THE CF GENE



Cystic fibrosis is a hereditary disease that affects about one in every 1,000 newborn babies. It results in an abnormally thick mucus secretion in the lungs that leads to severe breathing difficulties, lung infection and death. In spite of treatment, including a special diet, antibiotics and special massage, most sufferers die before the age of 30. In August 1989, however, researchers in Toronto, Canada, and Michigan, USA, pinpointed the gene responsible for the disease. While a 'cure' is still some time off – best estimates are five to ten years – it is now possible to identify carriers with a simple blood spot or mouthwash test. Researchers are already working on drugs that will eliminate the effects of the defective protein within the gene that causes the disease.

the material moves through the gel. At a given time, the current is switched off and the material in the gel stained. The stripes produced are unique to the tissue tested.

Provided a piece of biological tissue – blood, hair or skin – has



Thermography uses heat-sensitive sheets to make a temporary image. A camera produces a record (above) to study disease or injury and subsequent treatment.

the bodies of patients. Sheets of crystals impregnated into plastic film are pressed against the body area under examination and the crystals are warmed – colour changes indicate the degree of warmth.



Colour zones

The crystal sheets are photographed and the colour zones interpreted. This way, tissue damage may be seen directly and, by repeating the procedure over a period of time, the effectiveness of treatment can be fully assessed.

Genetic fingerprinting (see FUTURES, page 22) uses the unique genetic component of people to identify and/or match tissues. Protein from an individual gives a characteristic pattern when separated using

electrophoresis. This involves a small amount of tissue fluid being placed in a gel and an electric current applied across the gel for a certain period. The molecular size of the biological material determines the speed that

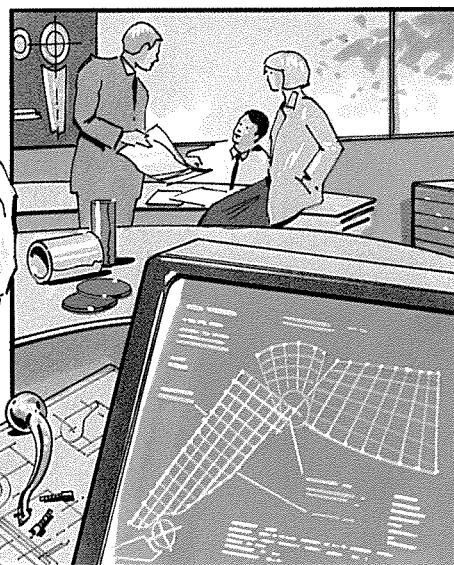
been left at the scene of a crime, this method can be used to help catch and convict criminals and, even more important, establish beyond question the innocence of other potential suspects in a case.

INTO THE FUTURE

BIOLOGICAL ENGINEERING



▲ Biochemical surgery and manipulation will end hereditary disease and will also enable parents to decide the look, hair and eye colouring of their children.



▲ Advances in computer technology and materials will mean that engineers and surgeons will work together to produce functional, lifelike replacement limbs.



▲ Eventually, Man will learn to tap the hidden powers within his own body to induce self-healing and create and maintain a state of permanent health.



ALL ABOUT

THE APPEARANCE OF GHOSTS, strange unaccountable noises, inanimate objects flying around, a person that levitates or speaks in strange voices — all are manifestations of the paranormal, phenomena outside the range of normal scientific investigations.

The study of paranormal activity or, to give it its modern name, parapsychology, is perhaps one of the most demanding areas of scientific research. Not only do ghosts and other inexplicable phenomena rarely perform to order, orthodox scientists do not even accept the evidence that paranormal research produces.

Minilab

Perhaps the most famous group dedicated to experimentation with the paranormal is SORRAT (the Society for Research into Rapport and Telekinesis) in the USA. When it was formed in 1961, SORRAT was simply a group of researchers into the paranormal that met in order to produce movement of objects and noises through the harnessing of psychokinetic 'energy'. It began to at-

Mary Evans Picture Library



The ghost of Raynham Hall, Norfolk, UK, claimed to be a woman, was captured on film by a Captain Provand in 1936 as it drifted down the staircase.

tract great fame and no little notoriety in the mid-1970s, however, with its use of the 'minilab'. Designed by PK specialist William Cox to 'trap' phenomena, this is an upturned aquarium with a sealed bottom, containing objects for the PK energies to play with. A movie camera is set up to record automatically any movement inside.

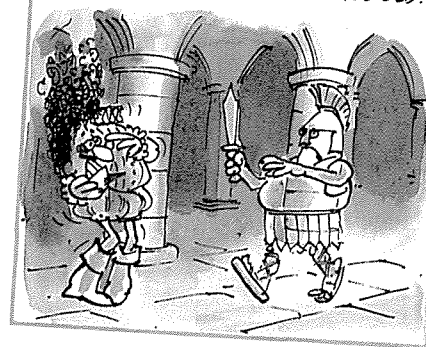
Since 1977, when the first films were shown, 'Cox's box' has become

A ghostly image that appeared on a picture of Limassol Bay, Cyprus. The photographer maintains that there was nothing there when he took it.

Just amazing!

LONG-LIVED GHOSTS

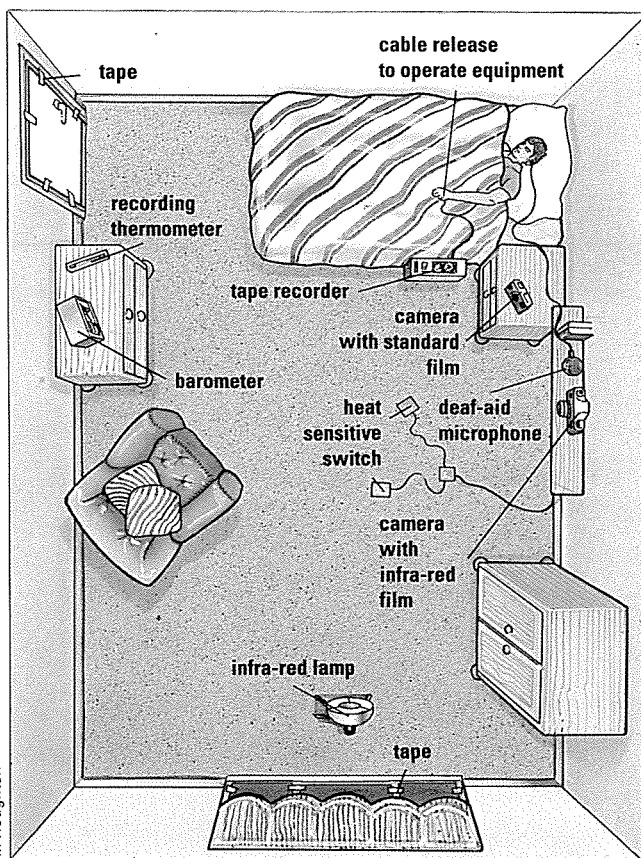
ALTHOUGH GHOSTS NORMALLY DIE AFTER 400 YEARS, YORK MINSTER, UK, HAS HAD RECENT SIGHTINGS OF THE GHOSTS OF ROMAN SOLDIERS — 19 CENTURIES OLD!



Paul Raymond

George Kanigowski/Fortean Picture Library

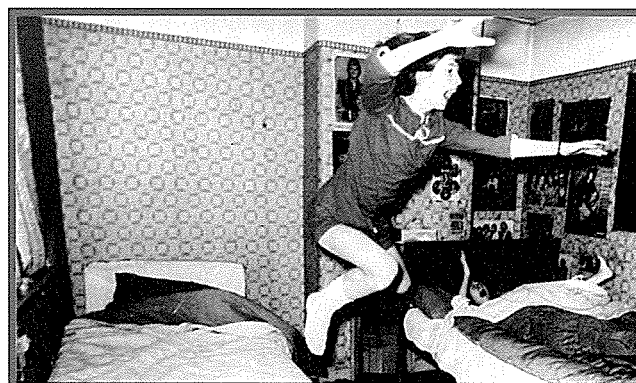




A parapsychologist will seal off a room in which strange events have been reported and attempt to detect and record any paranormal phenomena with a host of equipment. A length of thread is run around the room and arranged to trigger a camera loaded with infra-red film if anything brushes against it.

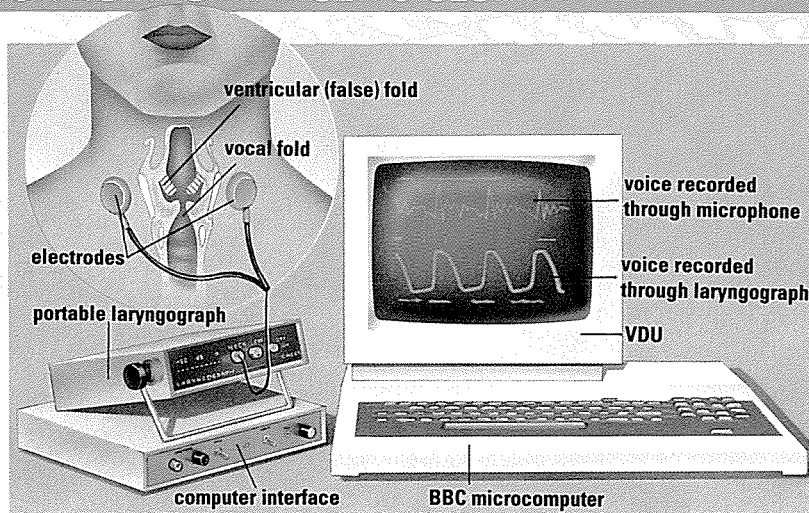
GHOSTSPEAK

ESP (Extra Sensory Perception): an extra sense, such as telepathy, outside the five known human senses
poltergeist: a 'noisy ghost'
psi: the umbrella name given to all psychic abilities and phenomena
psychic: force that has no physical explanation
psychokinesis (PK): the ability to move or change objects with the mind
telepathy: the ability to communicate thoughts over any distance



Graham Morris

LOOKING AT STRANGE VOICES

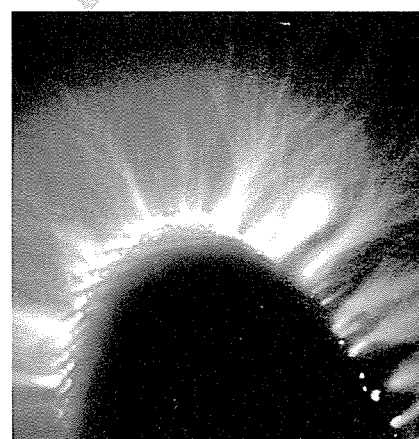


Among the many phenomena occurring in the Enfield poltergeist case was the voice of an old man that came from Janet, the young girl at the centre of the paranormal activities. Psychic researchers used a laryngograph to test whether Janet was simply reproducing the voice herself. This device monitors the action of the larynx by passing a high frequency signal

between two electrodes positioned either side of the throat. It was found that the voice came not from the larynx, but from the ventricular or 'false' vocal fold. Normally, it is impossible to produce sounds from here for more than a few minutes without damaging the throat. Yet Janet's 'voice' continued conversation for hours without any apparent discomfort to her.

Kirlian photographs are produced by passing the subject between two metal plates, on one of which is a sheet of photographic film, while a current is run from one to the other. The 'auras', shown here around a fingertip, may be evidence of an electrical 'life' field within all creatures.

Poltergeist activity was well documented in a case that occurred in Enfield, North London, UK, in 1977-78. Janet, the girl at the centre of the activity, was captured by Daily Mirror photographer, Graham Morris, apparently flying around a bedroom.



Novosti/Science Photo Library

the source of heated controversy. The films show such phenomena as packs of cards sorting themselves into suits, pens writing by themselves, spontaneous combustion of objects and rubber rings linking and unlinking, then jumping through the glass wall of the minilab.

Whenever paranormal activity is discovered and verified 'in the field',

investigators try and reproduce the effects in a laboratory. In Enfield, North London, UK between 1977 and 1978, there occurred a series of paranormal events manifesting from a young girl that resulted in one of the best documented cases this century. Members of the Society for Physical Research recorded examples of levitation, the strange voice with which

the girl spoke and other strange noises. Then she underwent tests at London University, UK, to see whether she could levitate or show abnormal powers under controlled conditions. At first nothing happened, then suddenly two weight increases of about 1 kg, each lasting about 5 seconds, were recorded. No explanation could be found.

NAVIGATION

Racal Marine Electronics Ltd



The Normand Skipper ploughs through the North Sea, taking supplies to an oil rig. To find the way, every ship must have navigation equipment on board. Many use Racal-Decca integrated systems (left), which include radar displays, a navigation processor that calculates the ship's position at any given moment and a colour video plotter.

Tony Stone Photo Library, London

WHEN THE FIRST SAILORS set sail, they steered by the stars. Modern mariners are also guided by the heavens - but it is satellites that show them where they are and, instead of looking up at the skies, they look down at a computer screen.

That is essentially what the modern navigator has to do: look. On the bridge of a modern ship, the sophisticated modern navigation system is connected to the autopilot. Once details of the voyage have been programmed in, the ship steers itself.

Navigation literally means 'ship-driving'. A navigation system must get

the ship to its destination on time and without accident. As sea routes become more and more busy, collision avoidance is growing in importance. Ships may be large and easily seen, but they are also hard to manoeuvre, slow-moving and require a long time to stop.

One of the main satellite navigation



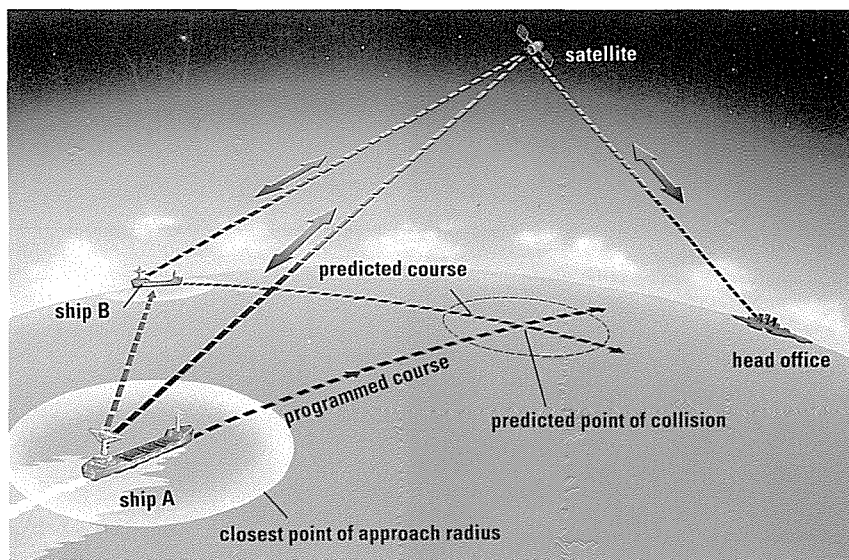
systems is the US Air Force's NavStar Global Positioning System (GPS). Eighteen satellites orbit the Earth at an angle of 63° to the Equator and the signals they transmit scan the surface of the Earth.

Each satellite sends out a signal on a precise schedule timed by an atomic clock. On board ship, a receiver automatically selects signals from the three or four nearest satellites and feeds them into a computer.



Position fixing

The computer works out the time delay between when each signal was sent and when it was received. This gives the ship's distance from each of the satellites. From these figures the computer can work out exactly where the ship is.



In the future, merchant ships could be unmanned – sailed by computers. Radar, computer and satellite systems will combine to avoid collisions. Ship A's radar would forecast that ship B will come dangerously close. This would trigger contact with ship B and head office, so the ships' courses could be altered.

Portland Bill
lighthouse on the south coast of England. Its electric light burns with a 3,370,000 candle-power intensity, seen from 47 km out to sea.

Inmarsat (International Maritime Satellite Organization) that includes other satellites sent up by Inmarsat. The system monitors the airwaves around the clock for automatic distress signals. Equipment on board automatically uses the satellite communication system to broadcast the name of a ship when it is in distress, also using the satellites to establish the ship's precise position.



Search and rescue

The system is known as COSPAS-SARSAT – SARSAT stands for Search and Rescue Satellite Aided Tracking System (COSPAS is the Russian equivalent). It is also used to direct search and rescue services and salvage ships to any vessel in distress. In its first five years of operation it saved over 1,000 lives.



Mayday

If a ship is sinking, and its on-board transmitter no longer works, an Emergency Position-Indicating Radio Beacon takes over. This is a transmitter weighing 50 kg that

St Mathieu lighthouse
in Brittany, France.

Each main lens is surrounded by glass rings that refract the central light, producing a beam with a range of 45 km.



Gamma/Frank Spooner Pictures

Precise details of any variation in the orbit of the satellite and the time intervals between transmissions are broadcast with the signal in a data stream. This means the on-board computer can make any adjustments necessary to make the position fix as accurate as possible.



Global coverage

GPS actually provides two services. The Precise Positioning Service is very accurate and reserved for use by

the military, and the other is the Standard Positioning Service, which is available to other users. This can fix a vessel's position anywhere in the world to within 10 metres. In addition, the USSR has its Global Navigation Satellite System (Glonass) which uses 12 satellites to give global coverage.



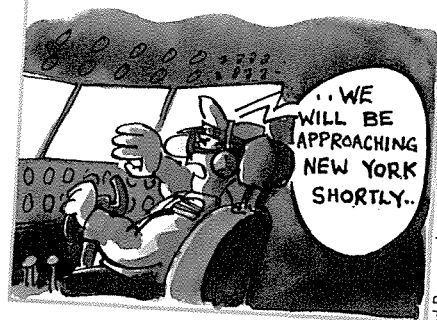
Distress system

The Russian and the American systems have been integrated into a single global distress system by

Just amazing!

LIGHT FANTASTIC

EACH NAVIGATION LIGHT ON THE EMPIRE STATE BUILDING IN NEW YORK SHINES WITH THE INTENSITY OF 450 MILLION CANDLES AND CAN BE SEEN FROM AS FAR AWAY AS 490 KM.



Paul Raymond



A lightship warns other ships of dangerous waters. It is moored above sandbanks and shoals, where a lighthouse cannot be built.

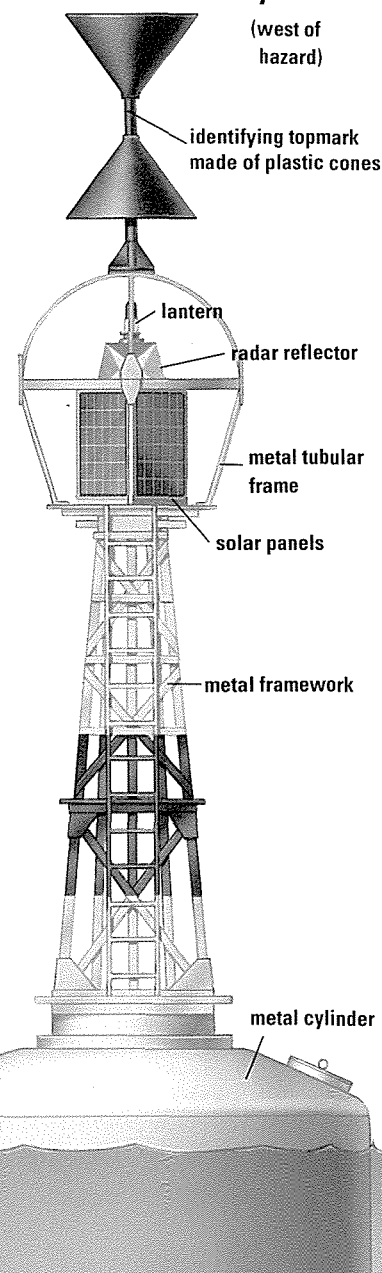
computer. At any time during the voyage, the computer will display the ship's position, the proposed course and any deviation from it that may have been caused by tides, currents or gale force winds.

The automatic pilot will make any necessary adjustments and work out when to begin the turn to make a 'smooth steer' between one leg of the voyage and the next.

Naturally, course alterations can be made during the voyage by moving

Solar-powered buoys are replacing other lighted buoys, because they do not need to be refuelled. Trinity House (the General Lighthouse Authority for England, Wales, the Channel Islands and Gibraltar) paints buoys in different combinations of yellow and black to show whether the buoy is north, south, east or west of the hazard or shipping lane that it marks.

Cardinal Class I Buoy



automatically sends out a distress signal when it is immersed in seawater.



Plotting a course

Inmarsat began operations in 1982. For the first time shipping had a communications system reserved solely for its own use and designed for its own purposes.

Inmarsat is funded by member

COLLISION AT SEA

Despite all the modern equipment available, ships still run into each other. These collisions usually occur because of human error, in crowded waters, in heavy seas and often when visibility is poor. But visibility was moderate to good in the Humber Estuary on the north-east coast of England early on 19 September 1989, when two oil tankers collided – the *Philips Oklahoma* running into the *Fiona*. Although more than 40,000 ships pass through the estuary every year, the nearest coastguard station was some 64 kilometres away and did not have the radar equipment necessary to warn of the impending collision. The impact tore a seven-metre-long gash in the *Philips Oklahoma*, spilling more than 200 tonnes of oil into the North Sea. Fire forced 16 Filipino crewmen on the *Philips Oklahoma* to abandon ship.



Ambrose Greenway

Lighted buoys warn ships of shallow water and mark sea lane boundaries. Gas-powered buoys must have their gas cylinders regularly refilled.

countries, and runs coastal stations, (as do most maritime nations). Signals sent out by these stations are picked up by a receiver on board ship and fed into a computer to give an accurate fix when the ship is nearing land.

When planning a voyage, the navigator fixes several 'waypoints', by feeding the longitude and latitude of points that the ship should pass during the voyage into the navigation

waypoints or entering more into the computer.



One-way traffic

Details of the course are stored on floppy disks so that they can be easily be transferred from one ship to another. Video maps of estuaries and harbour facilities are also available on disk so that when a ship reaches its destination port the same system can be used to steer it safely into its berth.

Modern lighthouses, lightships and danger-marking buoys broadcast radio and radar warning signals that are fed into the system. Lightships and large warning buoys are also used to mark out one-way traffic lanes in busy waters.

In the English Channel, for example, east-bound shipping must stick to a southern lane, nearer the French coast. West-bound shipping must stick to a northern lane nearer

Paul Williams



the English coast. Between them there is a separation zone and there are also inshore zones solely reserved for inshore traffic.

Yachts and cross-Channel ferries still cause problems, dashing across the sea lanes like pedestrians on a motorway. But on modern cargo ships plying up and down the Channel, the whole traffic system can be displayed at the press of a button.

Radar is also used to avoid collisions and sonar devices to warn

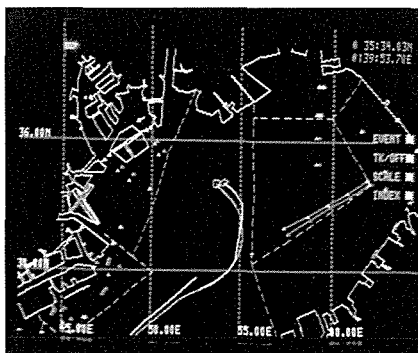
the ship's officers of shallow water.

The navigation equipment on most ships is integrated into the communications system as a whole. The development of maritime satellite communications is having an impact as great as the invention of the wireless telegraph around the beginning of the 20th century.

Spreading the news

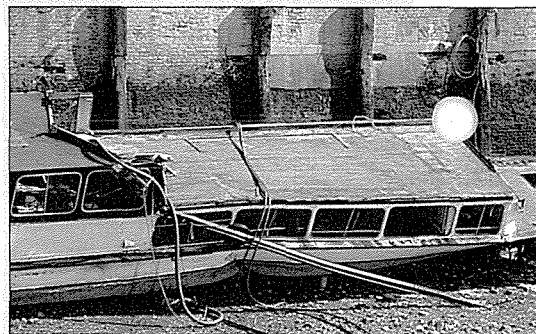
Many modern ships have ship-to-shore telephones, connected via satellite to the land. Equipment automatically scans the distress frequencies. Large ships have telex and fax facilities. Some have computer data links with their head office and on-board TV that gives up-to-the-minute maritime information.

The Panama Canal, connecting the Atlantic and Pacific oceans through the Isthmus of Panama, is one of the most important artificial waterways in the world. Up to 70 ocean-going ships pass through the canal each day. To avoid collisions, shipping observes a strict system of traffic lanes.



Colour Video Plotter (CVP) map of Tokyo Bay. A detailed map of a harbour can be plotted on board an approaching ship by entering into a CVP the longitudes and latitudes of points along the route.

THAMES DISASTER

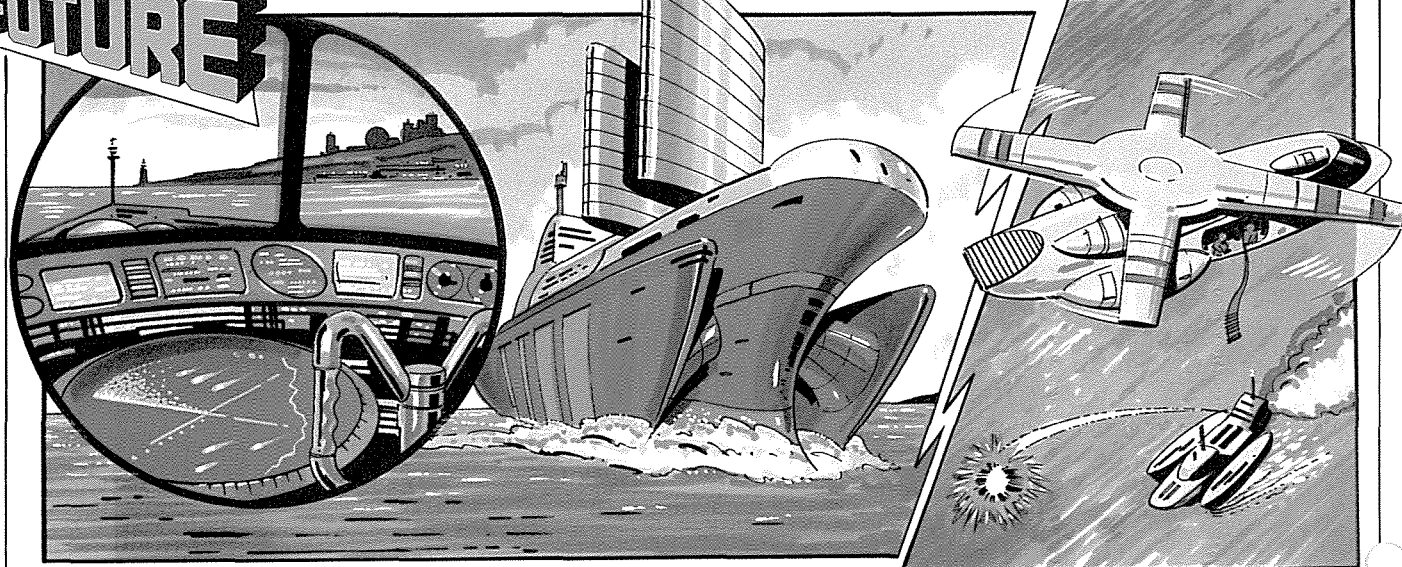


The *Marchioness* pleasure boat was almost through the central arch of Southwark Bridge, spanning the River Thames in London, when the *Bowbelle*, a sand dredger four times its size, came up from behind at speed. The dredger smashed into the stern of the smaller boat, forcing it to slew round. The *Bowbelle* then drove into the side of the *Marchioness* and within two minutes the pleasure cruiser had sunk. Fifty-five passengers, most of them guests at an all-night party, drowned. The accident happened early in the morning on 20th August 1989. The boats were attempting to pass through the central arch of Southwark Bridge at the same time, each unaware of the other's position. Only commercial boats such as the *Bowbelle* have to keep the Port of London Authority informed of their movements by radio. Pleasure boats must have a radio on board so that they can monitor shipping movements, but in this case the system did not work. As a result of this tragedy control over traffic on the Thames has been tightened.

Gamma/Frank Spooner Pictures

INTO THE FUTURE

GHOST SHIPS OF TOMORROW



▲ Computerized ship-board navigation and cargo handling systems may reach such a point that a crew is no longer necessary on board a cargo ship.

▲ A ship could sail on the open sea and in and out of port without a human hand touching the controls – the oceans could be host to a fleet of 'ghost ships'.

▲ A crew would be put on to a ship by helicopter for particularly tricky manoeuvres, or when emergency systems put out a distress signal.

Joe Lawrence



OIL SHIPS

HUGE SUPERTANKERS CROSS the oceans of the world carrying a total of over 60 million 'barrels' of oil every day — a 'barrel' being 42 US gallons of oil. These half-million tonne monsters can be up to a third of a kilometre long and each one may carry nearly two million barrels of oil.

Tankers are now as large as current designs allow. Should a tanker gets to be as long as the distance between the peaks of two Atlantic storm roller waves, it could find its bow and stern on the peaks of the waves, while its middle section would be clear of the water in the trough. This would probably cause the ship to break in two.



Articulated hulls

In the deep ocean, storm rollers have waves around 400 metres apart. Current supertankers tend to be around 300 metres long. To make tankers longer, it has been proposed that they have articulated hulls. This means that sections of the ship would be held together by huge hinges at deck level which would allow the ship to bend round the shape of the wave trough.

Although huge tankers are vital

Tony Stone Photo Library, London

Oil tankers are the largest and heaviest vessels on the oceans. Once they get up to full speed, they take many kilometres to stop or change course, even at speeds as low as 25 km/h





244

British Petroleum

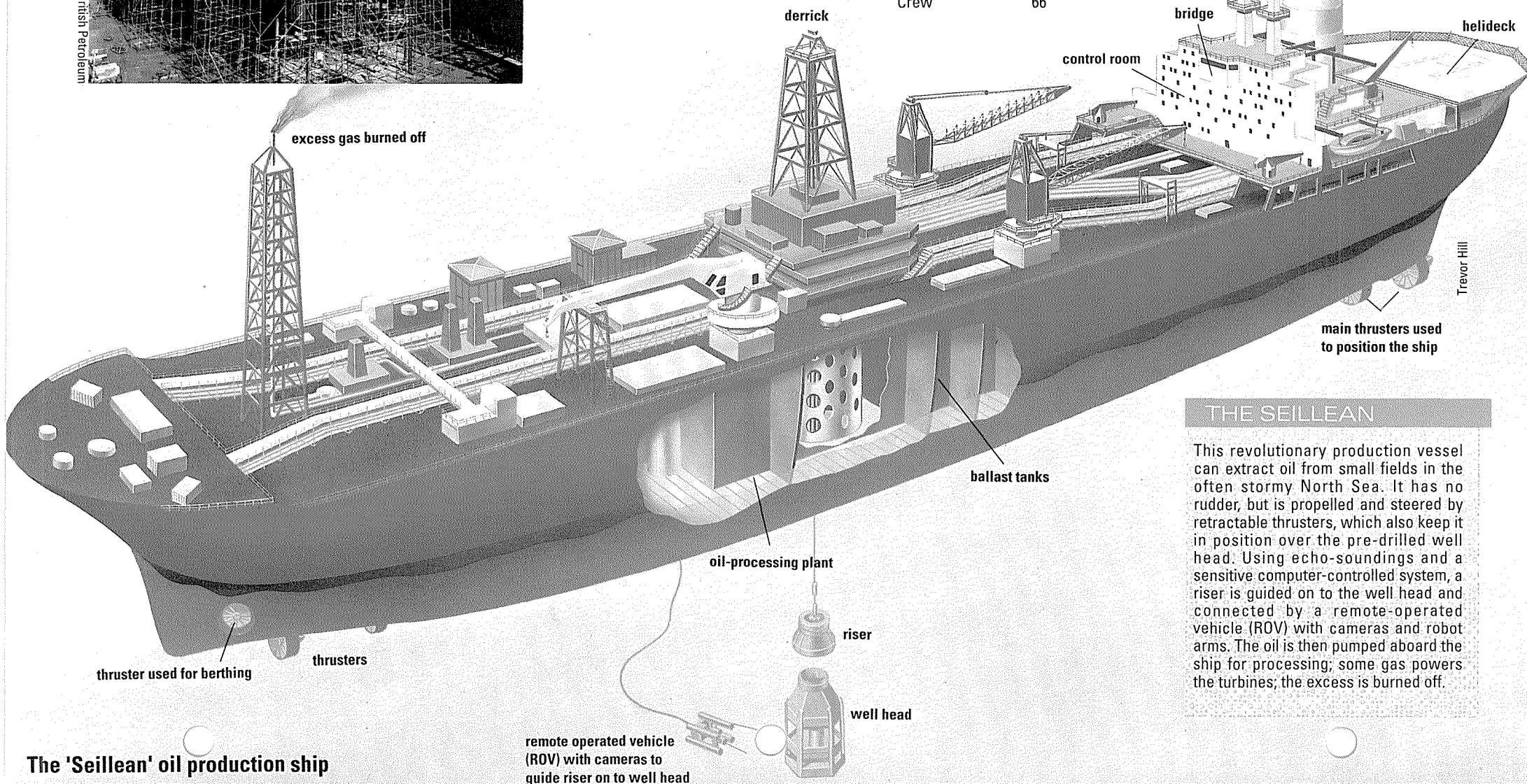


The Seillean
(Gaelic for bee) was designed to mop up small pockets of oil beneath the North Sea without the aid of divers. It can handle up to 16,000 barrels of oil per day.

PROFILE

THE SHIP

Length	249.7 metres
Breadth	37 metres
Draught	11 metres
Displacement	76,440 tonnes
Drilling depth	75-200 metres
Transit speed	9.9 knots
Crew	66



THE SEILLEAN

This revolutionary production vessel can extract oil from small fields in the often stormy North Sea. It has no rudder, but is propelled and steered by retractable thrusters, which also keep it in position over the pre-drilled well head. Using echo-soundings and a sensitive computer-controlled system, a riser is guided on to the well head and connected by a remote-operated vehicle (ROV) with cameras and robot arms. The oil is then pumped aboard the ship for processing; some gas powers the turbines; the excess is burned off.

The 'Seillean' oil production ship

OIL SHIPS

the sides of the ship, thus acting like a double hull.

Around the world there are a number of superports such as Milford Haven in Wales, Rotterdam in the Netherlands and the offshore oil facility off Louisiana in the Gulf of Mexico, which can handle the Very Large Crude Carriers (VLCC) or the Ultra Large Crude Carriers (ULCC).

Loading at sea

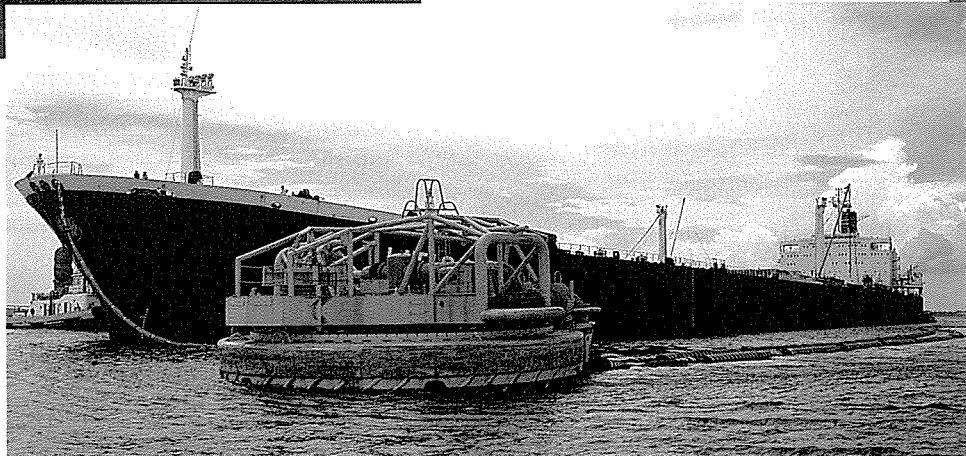
But most ports cannot handle supertankers. Instead, these ships have to moor to a buoy and load or unload out at sea. To make this safer, a new plug-in loading system is being developed. A huge, self-sealing socket, known as a pipeline end manifold (PLEM), is fixed to the end



Supertankers cannot get into ports such as Valdez (above), so they must load and unload at sea, by mooring to a large buoy with a pipeline attached.

for carrying oil around the world, they also carry great risks to the environment from pollution, either through the accidental or deliberate discharge of oil. But it should be remembered that the 390,000 tonnes of oil that enters the sea each year is only about 0.01 per cent of all the oil carried on the high seas.

The most spectacular type of spillage is when one tanker collides with another, or is grounded, like the *Exxon Valdez* off the coast of Alaska in 1989. Even the empty tanks carry



However, some oil companies claim that a double-hulled tanker could be more dangerous. With a single-hulled tanker, a hole leaks a small amount of oil, but when the pressure of the remainder equals that of the water, the leak stops.

With a double-hulled vessel, however, a hole would leak water into the space between the two hulls, increasing the risk of the tanker sinking. Oil companies also claim that double hulling tankers will make them more expensive — and the extra cost will push up the price of petrol, the main end-product of the oil industry.

New regulations

Although tanker collisions tend to grab the headlines, they account for only 10 per cent of oil spills at sea.

Another source of pollution used to be the deliberate emptying of ballast tanks at sea. An empty tanker must have several of its oil-carrying compartments filled with sea water ballast to weigh it down, otherwise the propeller and rudder would be clear of the water. But when the seawater was discharged from them, it flushed oil residue out into the ocean.

New regulations say that ballast tanks cannot be used to carry oil when the tanker is full. These ballast tanks, which now have to remain empty when the tanker is loaded, have to be situated at the bow and

of the pipeline on the sea bed. The tanker then carries a plug called a remote operated vehicle (ROV) on a long loading hose. When the tanker is in position above the PLEM, the plug is manoeuvred into position by water-jet thrusters. The ROV is positioned using a sound echoing system; once coupling is completed, the loading or unloading can begin.



Computerized control rooms have enabled shipping companies drastically to reduce crew numbers. As few as 15 men may now crew a giant tanker.

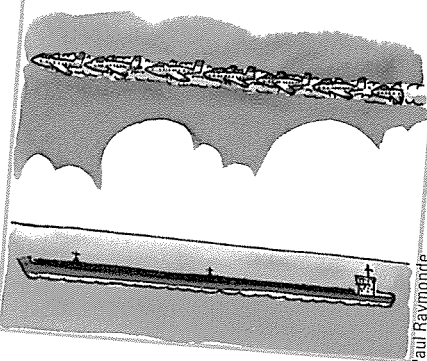
enough oil residue to pollute beaches and damage and kill wildlife.

One proposed solution is the double hull. American authorities may soon insist that all oil tankers using their ports must have two hulls — one containing the oil, and a second hull outside to protect the inner hull in the event of a collision.

Just amazing!

SUPERSHIP

THE WORLD'S LONGEST OIL TANKER, THE HAPPY GIANT, FORMERLY SEAWISE GIANT, IS 566 METRES LONG — THE LENGTH OF 7.5 JUMBO JETS!



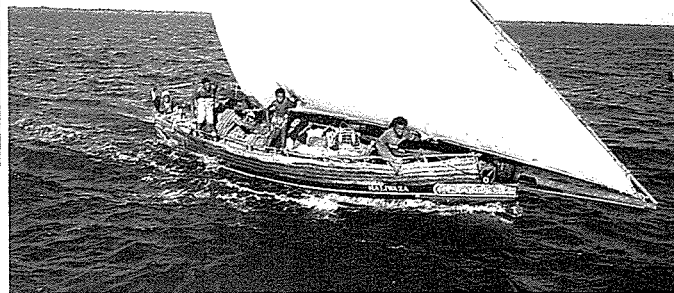
Paul Raymond



VIEW CARGO CARRIERS

A container ship passing through the Suez Canal. The canal links the Mediterranean Sea with the Indian Ocean, thus saving ships a long and hazardous journey around the coast of Africa.

Hutchinson Library



The dhow was used for centuries by Arabs to transport slaves and goods. Dhows still sail the old Arabic trade routes off the east coast of Africa and the Persian Gulf.

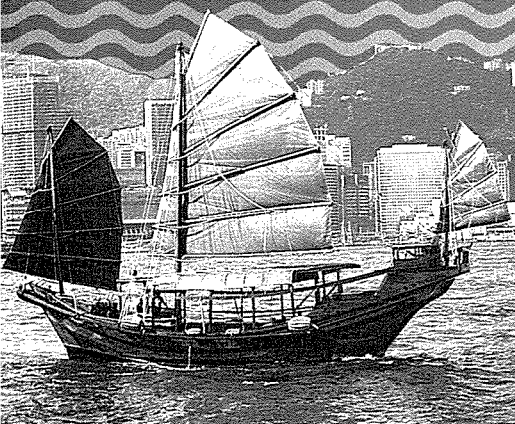
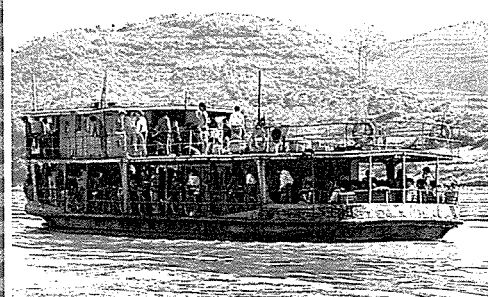
A passenger ferry crossing the river Mekong in China. This twice daily ferry is packed with goods, passengers and even livestock.

Hugh Jones/Planet Earth Pictures

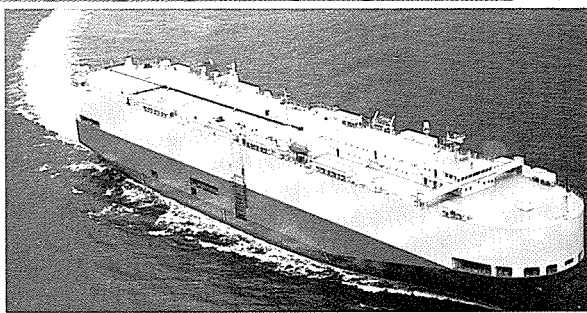


The Eternal Ace is one of the world's largest car carriers. Developed by a Japanese company to transport cars from continent to continent, it carries 6,500 cars at a time. The same company's 66 vessels can transport a total of 220,000 vehicles.

Jeremy Horner/Hutchinson Library



Hutchinson Library



Highly volatile liquefied natural gas (LNG) must be carried at -162°C . The crew are specially trained to operate these carriers at an LNG simulation centre in Japan.

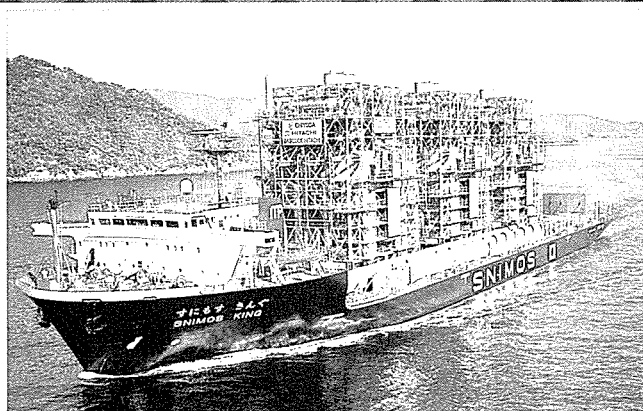
Traditional junks are still part of the Hong Kong skyline, but are now mostly decorative. They are a large version of the tiny Chinese sampan (which literally means three planks).

This module carrier can transport a whole chemical plant or similar structure around the world. The complete aft section of the ship is submersible to help unloading.

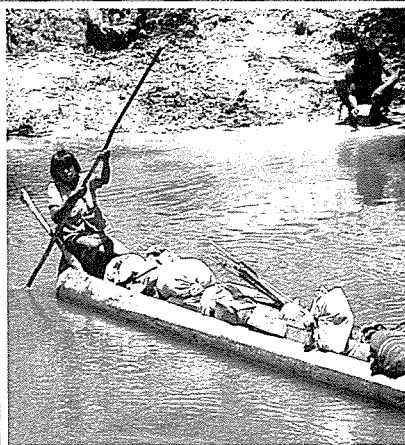


Mitsui O.S.K. Lines

Mitsui O.S.K. Lines



Hutchinson Library



A dugout canoe is the most ancient and basic water-borne cargo carrier. In some countries it is still the cheapest form of transport and is particularly useful in places where a larger boat cannot moor.



RESCUE AT SEA

LOCATING WRECKS

PRESERVATION

OPERATION SALVAGE

Wrecked ships attract the attention both of archaeologists wishing to preserve them for study and treasure-seekers wishing to recover valuables at any cost.

RECOVERING TREASURE

Chests of gold and gems from shipwrecks has been a dream of fortune-hunters for centuries.

However, throughout most of recorded history, this has been impossible unless the ship was driven on shore or sank in shallow enough water to be revealed at low tide. It is only really in the last hundred years that deep underwater recovery has been technologically possible.

Today, around the world, salvage companies are on alert day and night for news of ships in distress. This is not as ghoulish as it may seem because salvors, as the operators are known, also rescue crews if they are on the scene before the emergency

air-sea rescue services arrive.

Once a distress signal is picked up, ocean-going tugs race to the rescue of a disabled ship. The first that arrives gets the salvage contract - though if lives are at stake or the salvage operation presents special difficulties, joint contracts between separate companies may be made while their tugs are at sea.

Fire-fighting

When the salvors reach the ship, the tug takes off the crew. If the ship is in danger of sinking they then tow the stricken vessel to port. Fire is an extremely grave danger on ships - in particular on those vessels carrying oil, or any other inflammable cargo.

ZEPA



so salvage companies also have fire-fighting vessels.

Salvaging the giant oil tanker *Exxon Valdez*, which ran aground off Alaska in 1989, presented a number of problems. First, the inert gas system (used to pump the oil off) was boosted by low-pressure, high-volume blowers to force sea water out of the hull and refloat the vessel. Next, 400 stress-arresting holes were drilled, to prevent cracks spreading any further in the already badly damaged hull.



Helicopter rescue

The vessel was then towed all the way down America's Pacific coast to dry dock in San Diego. A helicopter belonging to the salvage company accompanied the *Exxon Valdez*, ready to take off the crew if a storm blew up, as the ship would have quickly broken up in high seas. Fortunately, the sea remained calm.

Outside San Diego, the huge pieces of the hull that had been



Pim Korver, Rotterdam

Floating cranes, capable of lifting 2,400 tonnes, were used to right the ferry *Herald of Free Enterprise*, which capsized off Zeebrugge, Belgium, in 1987.

large area of seabed. Pieces of the plane, particularly the black box flight recorder, have to be salvaged so that investigators can determine why the plane crashed.

Salvors find that, in this case, old-fashioned trawling is much more effective than high-tech methods. Huge areas of the seabed can be



NASA/Science Photo Library



Rond/Tani/Science Photo Library

Submersibles such as the *Mermaid II* and *Deepstar 4000* (above) are used to explore wrecks at depths down to 3,350 metres.

partially torn off when the ship ran aground had to be cut off before the ship went into dry dock. Some of them hung down more than 20 metres. Underwater cutting had to be done by divers in a heavy swell. Half-way through, they were menaced by schools of sharks.



Floating cranes

Salvors also have to deal with ships such as the *Herald of Free Enterprise*, which turned on its side at Zeebrugge on 6th March 1987. In this instance, massive floating cranes that can lift up to 2,400 tonnes were used to pull it upright again.

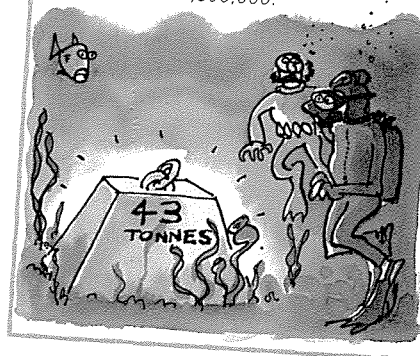
Salvors also use huge winches on the shore to lift sunken ships. Even so, some huge ships have to be cut into pieces to be raised. Only in very special circumstances is it worth raising a vessel that has been sunk in the deep ocean. A submarine is particularly difficult to locate as its exact position is often hard to pinpoint. Analysis of seawater in the area can reveal leaking diesel fuel and Geiger counters can be used to locate a nuclear submarine.

Aircraft downed over water are particularly hard to salvage. Usually they break up on or before impact, spreading thousands of pieces over a

Just amazing!

PIECES OF EIGHT

THE RICHEST TREASURE HAUL CAME FROM THE WRECK OF HMS LAURENTIC. DIVERS RECOVERED 43 TONNES OF GOLD, WORTH \$580,500,000.



Paul Raymond



trawled using ordinary fishing nets, which can retrieve large numbers of aircraft pieces, provided, of course, that the water is not too deep.

The other side of salvage is the work of the marine archaeologist who looks for sunken ships and their

Christian Pétion/Planet Earth Pictures



A marine archaeologist, wearing an aqualung, shakes the silt from a ceramic bowl recovered from the wreck of the Slava Rossi.

instead of just one. The resultant 'pictures' are almost as clear and detailed as a photograph.

Once the wreck has been located and its layout charted, the means of salvage is largely dictated by its

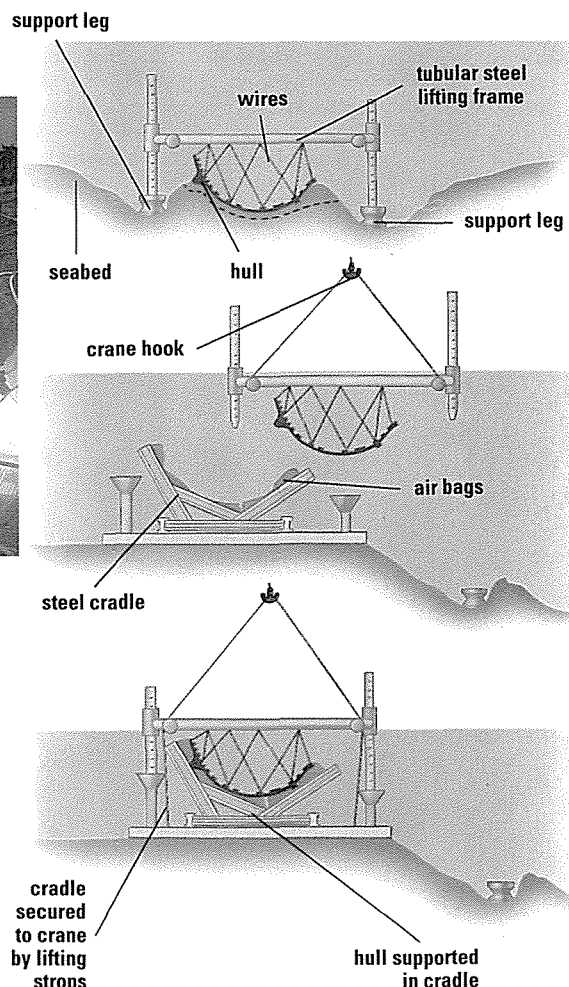
Divers stand by as a lifting bag is used to recover artifacts from the wreck of a Roman vessel the Ladispoli.

depth beneath the surface. Divers with aqualungs can operate safely down to depths of around 30 metres. If the wreck is in shallow water, the diving team will work in shifts clearing away debris and the silt and sand that inevitably cover the remains with a form of vacuum cleaner. This is also done to make it easier to examine the wreck and

TRACTOR TUGS

One of the greatest dangers for salvage tugs, even the giant 90-metre, 2000 tonne 'monster tugs', is that of being caught with their load – often up to 500,000 tonnes of supertanker or semi-submersible oil rig – off centre and being pulled over. For this reason, the water tractor was developed. Tractor tugs differ from conventional tugs in that their propulsion gear – rotating vertical blades much like giant egg whisks – protrudes downwards from the base of the hull rather than through the stern. This arrangement, known as the Voith-Schneider propeller, enables these vessels to turn in their own length and provides maximum thrust throughout the 360° of such a turn.

Raising the Mary Rose



The recovery of the Mary Rose, which sank just off Portsmouth, UK, in 1545 was carried out between January and October 1982. The hull was raised in a special cradle and taken to a dry dock in Portsmouth (above). There the hull is preserved by spraying with recycled, chilled fresh water almost continuously.

Mary Rose Trust/Mark Franklin

Mary Rose Trust

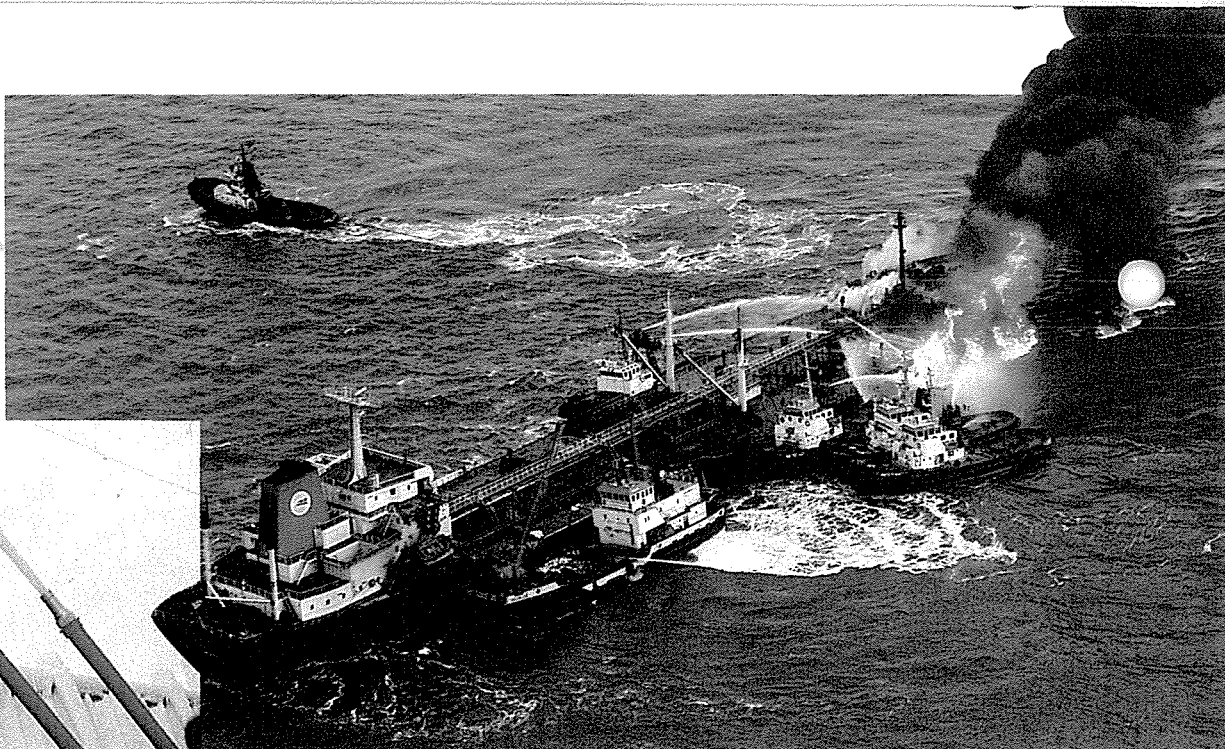


remains to add to our understanding of history. The first problem for the archaeologist is how to find the wreck. Contemporary records can be helpful in locating some vessels, but as the researcher moves back in time, luck plays a large part. Technology, in the form of sonar, can help, however, by enabling the seabed to be surveyed.

Sidescan sonar

Modern sidescan sonars (which search specific areas on either side of the transmitter rather than in a 360° arc around it) are able to build up composite scans of the seabed made up from a sequence of transmissions

Fire on board the tanker Olympic Dream – laden with 25,000 tonnes of petrol – is tackled by fire-fighting tugs. The high-pressure pumps (below) can operate successfully at temperatures as low as -40°C.



down from the surface. With enough air in it, the bag starts to rise, taking the object with it.

Mini-submarine

For wrecks such as the *Titanic*, which lies many thousands of metres below the surface, the only practical means of recovery is by means of a mini-submarine. This can be manned or unmanned and is equipped with TV cameras, lights and manipulator arms. If the vehicle is unmanned, an operator steers it by watching a TV screen which shows what the onboard camera is seeing.

Control commands are sent to the submarine by means of an umbilical cable that is wound out by the mother

ship. Once in position, the operator uses the manipulator arms to lift and secure objects that are to be brought to the surface. Manned salvage submarines work in much the same way, except that the operator crew is aboard the vessel rather than on the surface in the mother ship.

Preserving finds

Once an object has been brought to the surface, it frequently has to be treated to prevent exposure to air destroying it. The preserving process, which is particularly important for wood and metal, involves a thorough washing in clean water, in order to remove any encrustations, and the introduction of preserving chemicals.

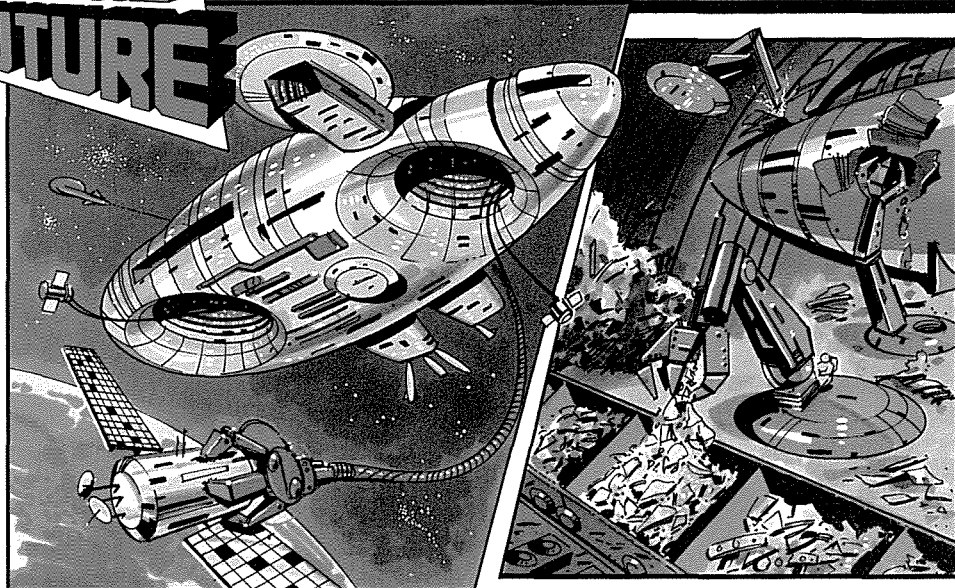
Smit Tak BV, Rotterdam

search for any valuable artifacts, such as coins or jewellery, it may contain.

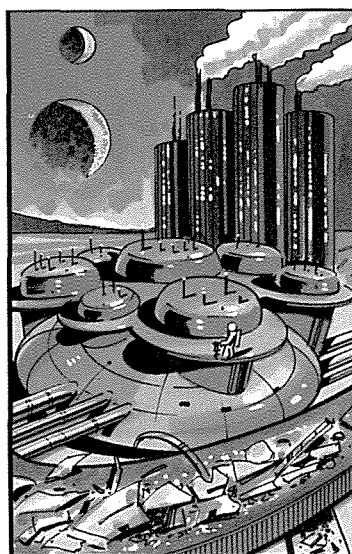
Heavier objects are taken to the surface by hand or, if very heavy, by means of air bags. The object to be lifted is attached to a bag (or bags); that is then filled with air pumped

Smit Tak BV, Rotterdam

INTO THE FUTURE



SCRAP IN SPACE



▲ Future salvage operators may look to Space rather than the seabed for hidden treasure, using vast 'scrap ships' to gather abandoned satellites, rockets and craft.

▲ The 'scrap ships' will be vast factories in Space, processing the scrap and recovering all valuable and reusable material before junking the rubbish.

▲ At planetary foundries, the scrap metal will be melted down in vast furnaces and used to produce new metal for a fraction of the original price.

Joe Lawrence



■ HYDROELECTRICITY

■ IRRIGATION

■ TIDAL BARRIERS

DAM

TAMING AND HARNESSING the power of mighty rivers, dams are among the biggest engineering projects in the world. Dams are designed to supply water for drinking and irrigation, to enable electricity to be generated by hydroelectric power and to stop flooding.

The objective of dam-building is to stem the normal flow of a river and cause its waters to accumulate as an artificial lake or reservoir. During summer, when the river would normally be low, the reservoir will continue to supply water. In winter, the reservoir may become so full that excess water has to be let out through special gates called spillways.



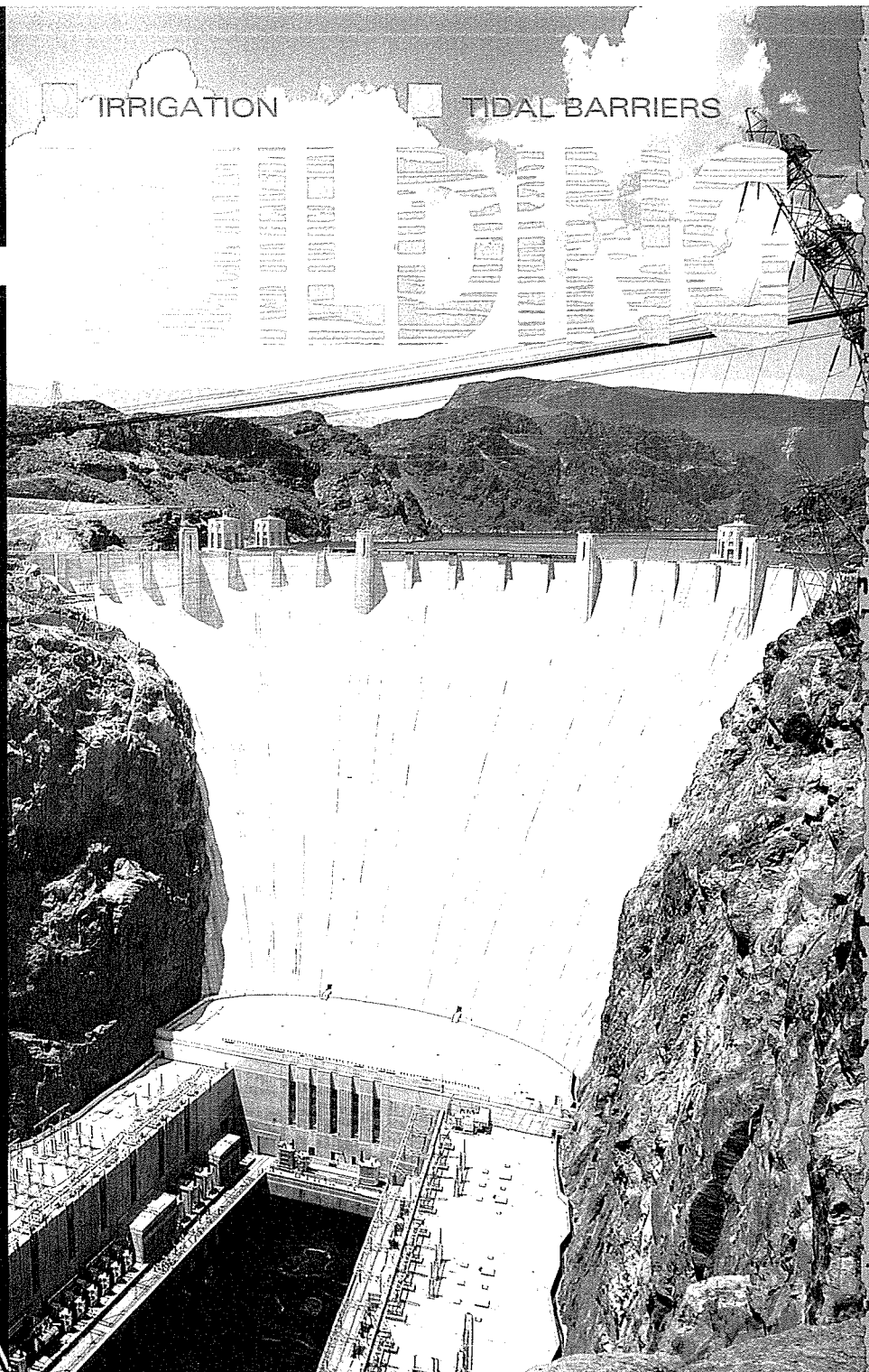
Drawing off water

In western Europe, many dams serve simply to hold back reservoirs of water for domestic and industrial consumption. The water leaves the reservoir by submerged pipes, is chemically treated to make it safe for drinking, and then enters the water-distribution network.

Irrigation dams are important in areas that have a very wet season followed by a hot, dry one. In the wet season, rain may be

Gamma/Frank Spooner Pictures

Telegraph Colour Library



The Hoover Dam near Las Vegas, USA, is a concrete cupola dam. It is built in a very strong shape, curving upwards and downwards as well as from side to side.

The Tucuruí Dam is part of Brazil's hydroelectric power programme, producing 8,000 megawatts from 12 turbines when at full capacity.





containing 190 million cubic metres of water.

Of the many dams that have been built to produce hydroelectric power, the 167-metre-high Grand Coulee Dam on the Columbia River in Washington State, USA, is among the most famous. Completed as long ago as 1942, it has a generating capacity of 6,500 megawatts.

Power to the people

It has now been far surpassed, however, by the 12,600-megawatt Itaipu Dam on the Brazil-Paraguay border. Plans to build a new power

George Wimpey plc

torrential, swelling rivers and causing them to flood – with catastrophic results for people and livestock in the surrounding countryside. By contrast, the rivers may stop flowing altogether in the dry season, leaving the land parched. An irrigation dam

DAMS THAT BROKE

Few disasters strike more suddenly and powerfully than when a major dam gives way. The worst recent accident of this kind was the collapse of the Manchhu River Dam in Gujarat, India, on 11 August 1979, when around 5,000 lives were lost. In 1963, a huge landslide into the reservoir behind the Vaiont Dam in Italy caused water to surge up to a height of 200 metres above the dam wall. The water poured down on to the town, killing 2,000.

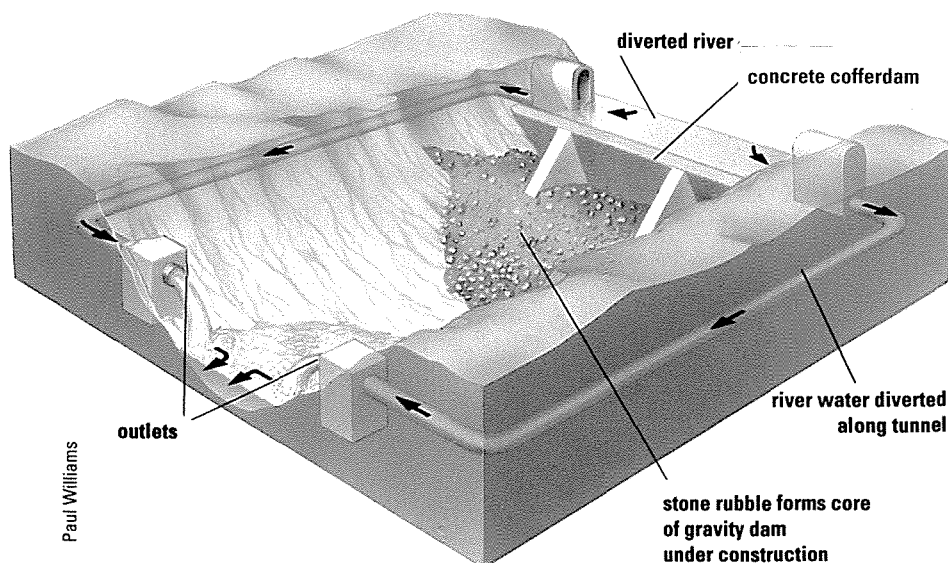
stores water in the rainy season so that it can then be distributed evenly to communities throughout the year. The Tarbela Dam in Pakistan, does just this. One of the world's largest, it stands 150 metres high, extends for 2.7 km, and holds back a reservoir

Llyn-Brianne Dam in South Wales. Normal draw-off of water from the reservoir, which can hold up to 61,000 million litres, is through two steel outlet pipes. At Marchlyn Dam (above), the dam was covered with a thin layer of waterproof asphalt and concrete mix.

A dam is built behind a temporary structure called a cofferdam. River water held back by the cofferdam is diverted around the site by specially constructed tunnels. The cofferdam is eventually incorporated into the permanent barrier.



Building a Dam



Paul Williams

station on the Tunguska River in the USSR capable of producing a staggering 20,000 megawatts of electricity were announced in 1982.

Hydroelectric power stations are situated near the base of dams so that water from the reservoir has to fall a considerable height to reach them. The water enters a series of steep pipes and is then channelled down to the machinery in the plant. There it spins the blades of giant turbines that, in turn, are connected by shafts to a number of generators. Finally, the electricity produced by the generators enters the national grid for distribution to homes and factories.

Diversion tunnels

Before a dam can be constructed, the normal course of a river has to be temporarily diverted so that the dam site is left dry and workable. Often

George Wimpey plc

Gamma/Frank Spooner Pictures



Clay was a major material used in the construction of a 3,000-metre-long embankment dam across the River Feni in Bangladesh in 1985. Bags were filled at the river's edge with clay brought down from the Chittagong Hill Tracts.

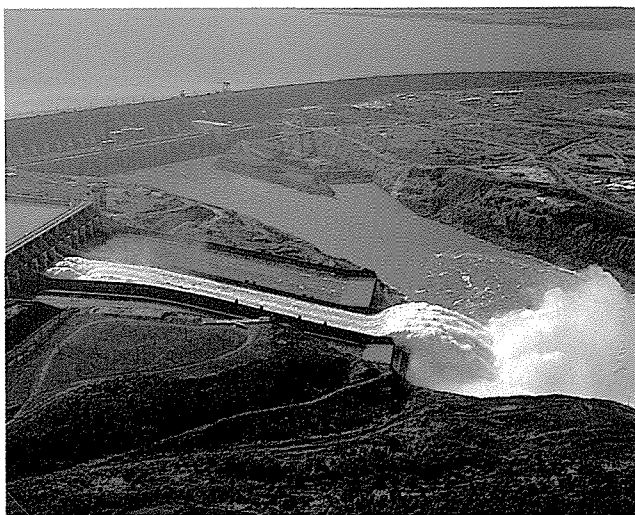
this is done by digging underground channels in the valley's sides. Large mechanical excavators then scrape away at the old riverbed until they have exposed solid rock, on which the dam's foundations are built.

The dam itself may take one of several main forms. The Tarbela Dam, for instance, is an embankment dam, a heaped up mound of hun-

extends deep into the ground to prevent water from seeping underneath.

The Grand Coulee Dam is, like embankment dams, a gravity dam. It relies on its enormous weight - over 20 million tonnes - to hold back the reservoir of water behind it. But in this case, the dam wall is built from concrete. In cross-section it has the

Over 28,000 workers took more than ten years to build the Itaipu Dam. Eleven million cubic metres of concrete was used in its construction.



The Itaipu Dam stretches nearly 8 km across the Parana river, which runs along the Brazil-Paraguay border. When running at full power, its hydroelectric power plant will produce 12,600 megawatts from 18 turbines.

shape of a right-angled triangle with the vertical side facing the water stored in the reservoir.



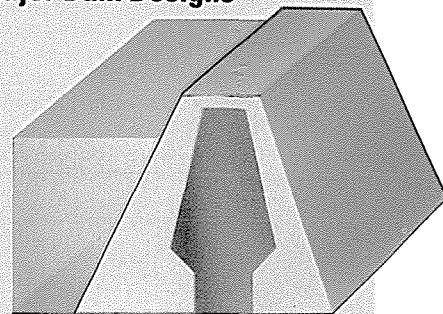
Strong shapes

The less bulky dams, which are cheaper and faster to build, have to rely on a strong shape rather than sheer weight to resist the enormous force of water. An arch dam, for instance, curves smoothly from side to side to give it greater strength. Such a design is particularly suited to damming a narrow gorge. The curve of the arch faces upstream, and the arch transmits the pressure of water along the sides. This means that the

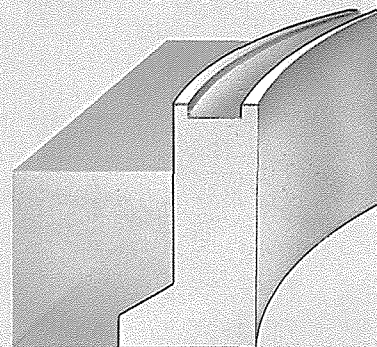
dreds of millions of tonnes of soil and rock. When finished, such a dam is very broad at the base (where it has to withstand the greatest water pressure) and slopes up gradually on each side to a fairly narrow crest. An embankment dam like this has a core of clay, or occasionally concrete, that

Dams are designed to hold water in huge reservoirs without crumbling. A gravity dam resists water pressure by its mass, an arch dam by distributing the load along the sides of the curve.

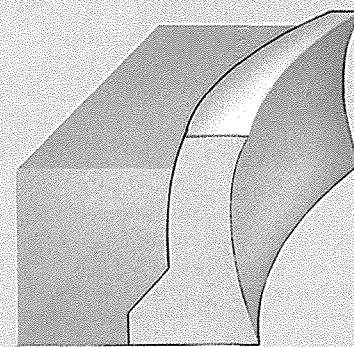
Major Dam Designs



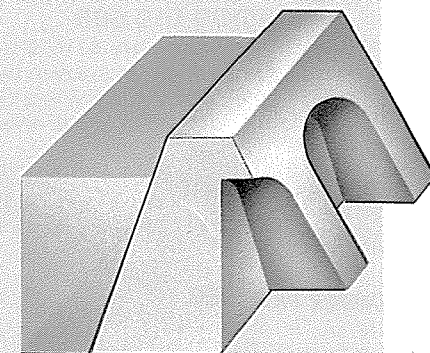
embankment or gravity dam



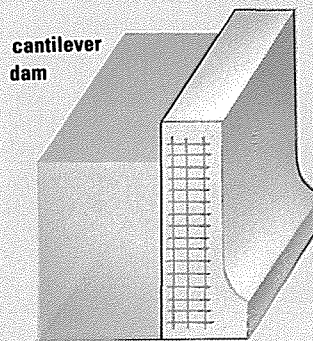
arch dam



cupola dam



long straight dam with buttresses



reinforced with steel cables

Kuo Kang Chen



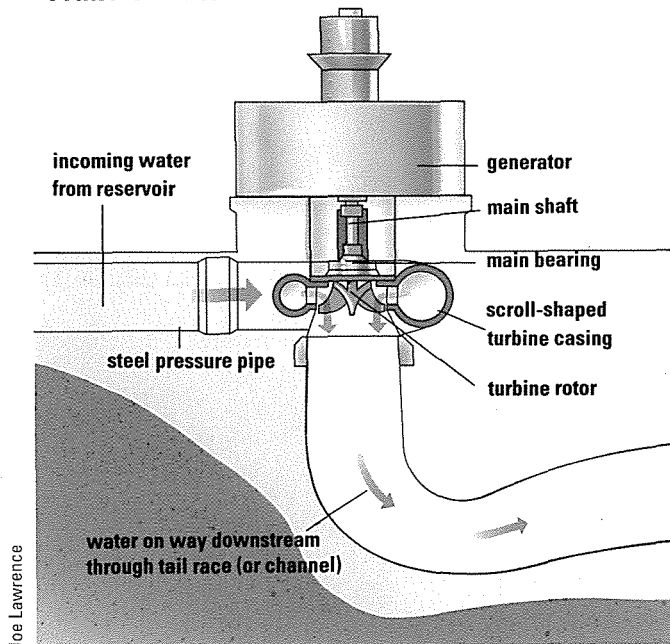
sides must be especially well founded on rock in the valley slopes.

A variation on this design is the cupola dam. This curves not only from side to side but also from top to bottom. An example is the 185-metre Reza Shah Kabir Dam, which spans a narrow gorge in Khuzestan, in south-west Iran.

Not all dams are built to the latest

rock. Next, the 15,000 workers on the project carted and placed hundreds of thousands of 45-kg bags of clay to make the dam. In one frantic 7-hour period at low tide on the 28 February 1985, 600,000 bags were put into position – by hand – to permanently seal off the river from the sea. Today, the reservoir successfully controls flooding and

Francis Water Turbine



Joe Lawrence

A water turbine in a power plant converts some of the energy in a stream of water into mechanical energy that generates electricity. The mechanical power is produced by water flowing through a pipe on to a system of stationary and moving blades. The Francis turbine is the most popular type because of the wide range of 'heads' with which it can be used. (The head is the height of water above the turbines).

engineering designs with hi-tech materials and equipment. Short of money and machinery but rich in manpower, the people of Bangladesh constructed a barrier across the mouth of the Feni River using muscle power alone.



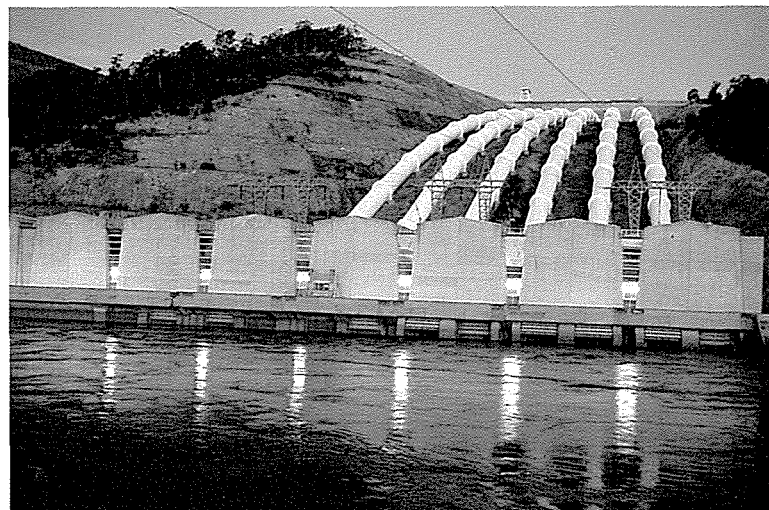
Stopping the sea

Under the direction of a Dutch engineer, they first laid down huge reed mattresses, which were then held in place with 250,000 tonnes of

supplies much needed fresh water for irrigating rice crops.

More advanced tidal barriers have been set up at several sites in Europe. In Brittany, France, the estuary of the River Rance was dammed in an unusual hydroelectric scheme. The tides at the mouth of

Tumut 3 hydroelectric power station is part of the Snowy Mountains scheme in New South Wales, one of Australia's greatest civil engineering projects. A double-decker bus has been driven up the pipes shown in the picture.



the Rance, rising 14 metres, are among the highest anywhere in the world. When the tide comes in gates in the dam open to allow the water to rush up river, but then close to trap the rising water temporarily in a reservoir. As the tide goes out, the trapped water is allowed back to the sea over a series of 24 turbines that are connected to generators.

A much larger sea dam has been built across the mouth of the Zuider Zee in the Netherlands to prevent flooding of the reclaimed lowland areas. Known as the Afsluitdijk, it stretches for over 30 km. Another highly sophisticated dam is the Thames Barrier across the River Thames, which protects London from flooding.

ANIMAL RESCUE



When the Itaipu Dam was built on the Brazil-Paraguay border, the cost to the environment was great. Almost 1,500 km of tropical rainforest and farmland was drowned by a giant reservoir and one of the continent's most striking waterfalls, the Sete Quedas, was lost for ever. A few weeks before flooding began in 1982, a special operation was launched to save as many wild animals as possible from drowning. Volunteers caught monkeys, lizards, porcupines, rats, spiders, turtles and many other species in the areas about to be covered with water, and then transported the animals to safety. Over 4,500 animals were rescued.

Gamma/Frank Spooner Pictures

Just amazing!

UNDER PRESSURE

THE SAYANO-SHUSENSKAYA DAM IN THE USSR WILL BE THE STRONGEST EVER BUILT. ABLE TO WITHSTAND 18 MILLION TONNES OF WATER PRESSURE EQUIVALENT TO OVER 3 MILLION CHARGING ELEPHANTS



Paul Raymond





ECO-ENGINEERING



CAR COMPUTERS



PLASTIC CARS

CAR CONSTRUCTION

Sautelet/Jarrigan



CARS ARE AMONG THE MOST highly engineered items in everyday use. From the engine to the dashboard, cars are at the leading edge of technology as people demand greater performance, comfort and fuel efficiency. The three main areas of engineering research today are the engine, construction materials, and computerized electronic systems.

The heart of a car is its engine. It provides the power that is transmitted through the gearbox to keep the wheels turning. Although the internal combustion engine works on the same principles as it did in the 1870s, its design and construction now belong firmly to the 20th Century.



Four-stroke engines

The four-stroke petrol engine burns a mixture of fuel and air. The mixture is created in the carburettor, from where it is drawn through an inlet valve into a cylinder (induction stroke). Inside the cylinder the mixture is then compressed by the piston (compression stroke) and ignited by the spark from a spark plug. The explosion forces the piston down (power stroke), turning the crankshaft in the process. The piston then rises, forcing the waste gases out of the now open outlet valve (exhaust stroke). The outlet valve

Tomorrow's car is here today. French manufacturer Peugeot have developed the Proxima as a car of the future. It has a Kevlar/carbon-fibre body with a glass canopy that opens overhead (right). Five video screens display information, and it has a new radio guidance system.



Sautelet/Jarrigan

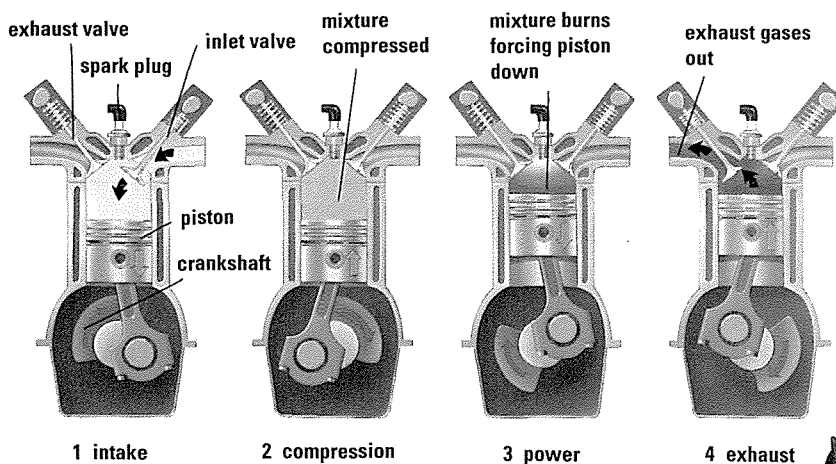
then closes and the inlet valve opens again, ready for the next intake of fuel and air.

The sequence of these events is staggered from one cylinder to the next so that the crankshaft is kept rotating smoothly. In an average family saloon at 90 km/h in top gear, the crankshaft turns about 50 times every second, or 3,000 revs per minute (rpm). The crankshaft is connected to the gearbox. This transfers the engine's power to the

driving wheels, which turn at about a quarter of the speed of the crankshaft.

The gears regulate the engine's output to suit the driving requirements - lower gears supply more traction for accelerating or going uphill, and higher gears are engaged for cruising at high speed. A reverse gear is used to drive the car backwards for manoeuvring. In neutral, the gearbox allows the engine to keep running while the car is





The Four-Stroke Engine

stationary. Most modern cars have front-wheel drive with the engine laid out across the engine bay. This means that the weight of the engine bears down on the driving wheels to give them better grip on the road.

Automatic transmission

Most cars still require the driver to depress a clutch pedal and select the gear manually, but many now have automatic transmission, where the gears change according to the engine speed. A recent development

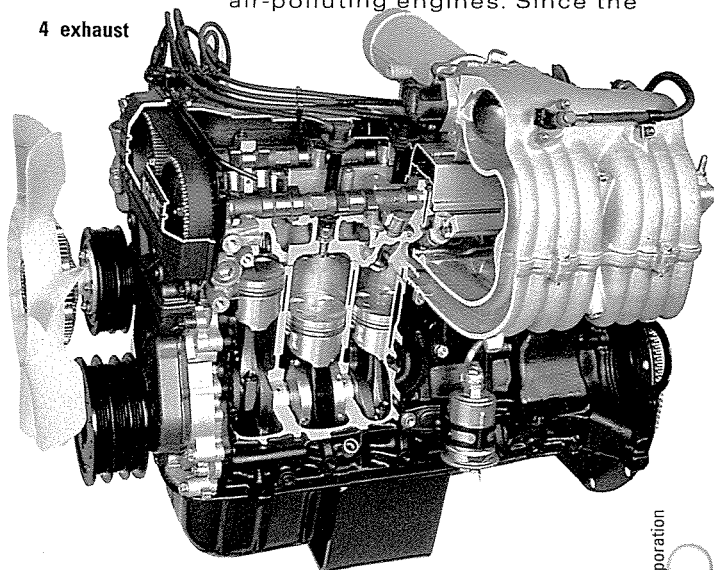
The four strokes of an engine (right).

(1) A petrol and air mixture is drawn in via the inlet valve. (2) The piston rises to compress the mixture, until a spark from the plug ignites it (3). The hot gases force the piston down, after which they are forced out (4).

at great pressure. When the highly compressed mixture is ignited it can produce up to 50 per cent more power than in a normal engine. Supercharging is a similar process, but this time the fuel is forced into the cylinders by a mechanical pump instead of exhaust gases.

Lean-burn engines

In today's highly competitive car market, engineers are always striving to increase engine performance. But in an increasingly ecology-conscious world, they have to design more fuel-efficient and less air-polluting engines. Since the



Toyota Motor Corporation

Many now employ 16 valves, four for each cylinder, to get more fuel into the system. This gives great power and fuel efficiency. Turbocharging is another technique for getting more power out of an engine. Waste gases going down the exhaust pipe are used to drive a pump - the turbocharger - which forces the fuel and air mixture into the cylinders

1970s, when US and Japanese governments brought in strict controls over exhaust emission, much research has concentrated on 'leanburn' technology. This still gives high performance, but reduces the amount of poisonous gases given off with car exhaust. Sensors in the carburettor linked to a central computer make the engines highly efficient by optimizing the fuel mixture and flow.

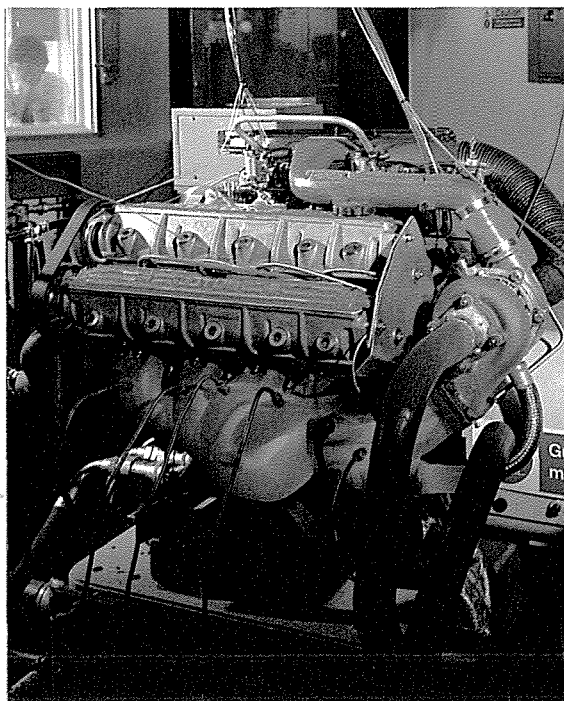
One beneficial change has been the switch toward lead-free petrol.

known as continuously variable transmission (CVT) allows the engine to run constantly at its most efficient speed. CVT uses a clever arrangement of expanding pulleys and a drive belt to provide any gear ratio between top and bottom gear.

Various methods are used to boost engine performance. One way is simply to increase the number of cylinders. While most ordinary cars have 4 cylinders, more powerful models may have 6, 8, or even 12.

Moulding fibreglass body panels. Lighter materials such as plastics are being increasingly used in place of steel.

The exhaust from a turbocharged engine is so hot that parts of the engine may glow bright red under hard driving conditions.



Lotus Cars Ltd

CAR CONSTRUCTION



An echo-free testing chamber is designed so that it will not reflect any sounds. This means that engine noises can be pinpointed exactly, and vibration problems can also be detected and ironed out.

In the 1970s, the need to reduce exhaust emissions brought electronic sensors into the engine for the first time. Since then, rapid advances have led to a wide range of computers and microprocessors being used in cars. As well as monitoring and controlling engine performance, sensors are widely used, for example, in anti-lock braking systems (see NEW TECHNOLOGY, page 179),

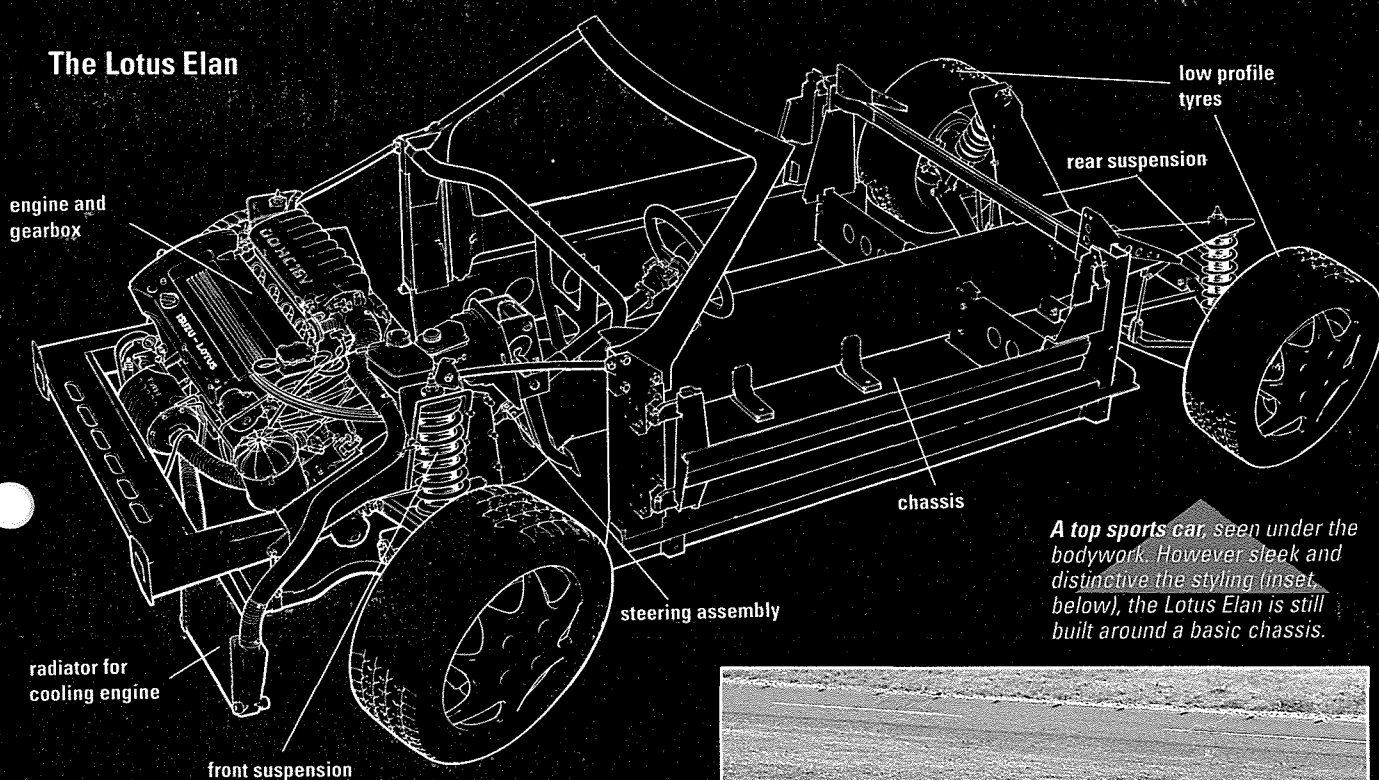


Rear-wheel steering

The Japanese company Toyota has produced a sports car with rear wheel steering. As the car turns a

Lotus Cars Ltd

The Lotus Elan



A top sports car, seen under the bodywork. However sleek and distinctive the styling (inset below), the Lotus Elan is still built around a basic chassis.

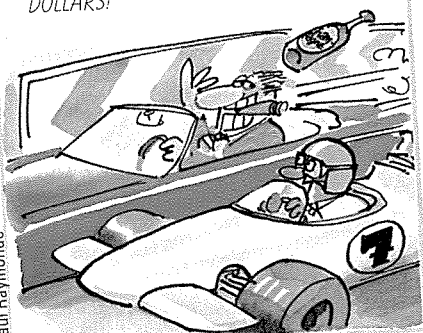


Lotus Cars Ltd

Just amazing!

FAST MONEY

THE NEW JAGUAR XJ220 WILL BE THE WORLD'S FIRST PRODUCTION CAR CAPABLE OF OVER 320KM/H. BUT IT WILL COST AROUND HALF-A-MILLION DOLLARS!



Paul Raymond

Lead was previously added to help engine performance, but it is very poisonous. Today, lead-free petrol can be used with very little loss of performance.

Catalytic converters

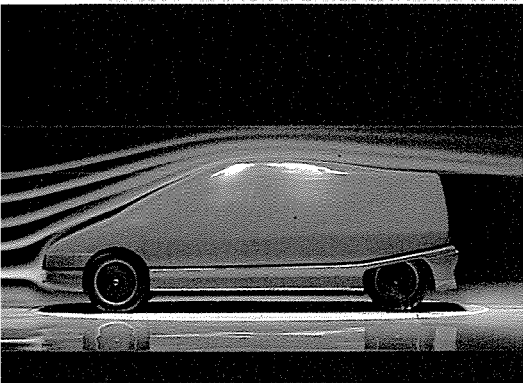
The use of lead-free petrol allows cars to use devices called catalytic converters on their exhaust systems, which convert harmful gases such as carbon monoxide into harmless ones.

corner or hits a side wind, sensors on the rear axle detect the rate of yaw, or sideways twist, and a computer activates the rear wheels to compensate. This model also employs sensors to check tyre pressure, and has a windscreen that turns into a liquid crystal sunshade at the flick of a switch

Trip computers can display information on journey time, average speed, and fuel consumption. On some experimental cars drivers have access to electronic maps that show



AERODYNAMICS - THE DRAG FACTOR



At high speeds, up to 80 per cent of engine power may go into just forcing a car through the air. The problem is that uneven lines or sharp corners disturb the air flow, causing turbulence which drags on the car. To reduce drag, engineers simulate different car shapes on supercomputers (see FUTURES page 79), then test prototypes in wind tunnels. Illuminated smoke trails reveal how air flows around the body, while the car sits on a sensitive balance that records the amount of drag. A good aerodynamic shape is something like a teardrop.

bodies moulded from plastic reinforced with 2cm-long glass-fibres.

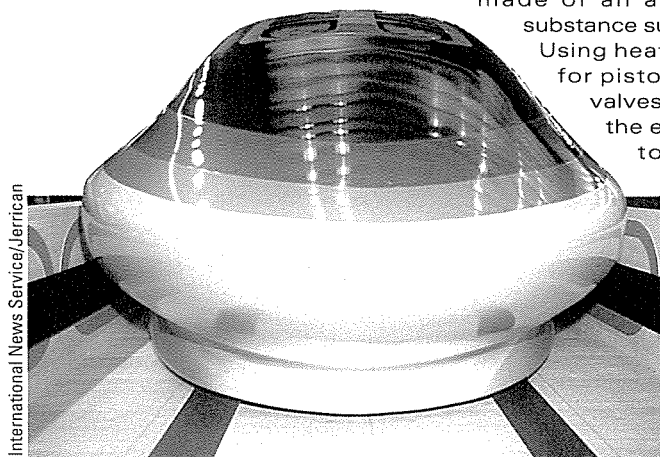
Even stronger materials such as Kevlar, which is used in bullet-proof vests, can be combined with carbon fibre, for body shells.

Hot Stuff

Metal engines, too, may soon become a thing of the past. Metal is not only heavy, but it cannot stand up to the high temperatures at which future engines will run. By the year 2000, some car engines may run at about 1,370° C, enabling them to use less fuel and cause less pollution. But instead of steel and aluminium, their high-temperature parts will be made of an advanced ceramic substance such as silicon nitride.

Using heat-resistant ceramic for pistons, cylinder liners, valves and turbochargers, the engine will not need to be cooled by a

The Linear Motor Express is a French vehicle capable of 500 km/h. It uses a linear induction motor, which lifts up the vehicle by generating a magnetic field over the track below.



International News Service/Jerrican

Bérengruer/Jerrican

a vehicle's current position and heading on a miniature screen. Others are fitted with satellite navigation equipment. Linked to a sophisticated radar system, an onboard computer could automatically apply the brakes or take over the steering if a collision seemed imminent.

Further into the future, cars may be able to travel at least part of the time without a driver at the controls. The required route and destination would be entered into an onboard computer that would take over as automatic pilot, using signals from a guidance system under the road.

New materials

In the past, cars were built mostly of steel, which is cheap and can be easily shaped and welded together. But in an effort to save weight and thus improve performance, a whole range of new materials are now being used for car parts.

Plastic bumpers that spring back

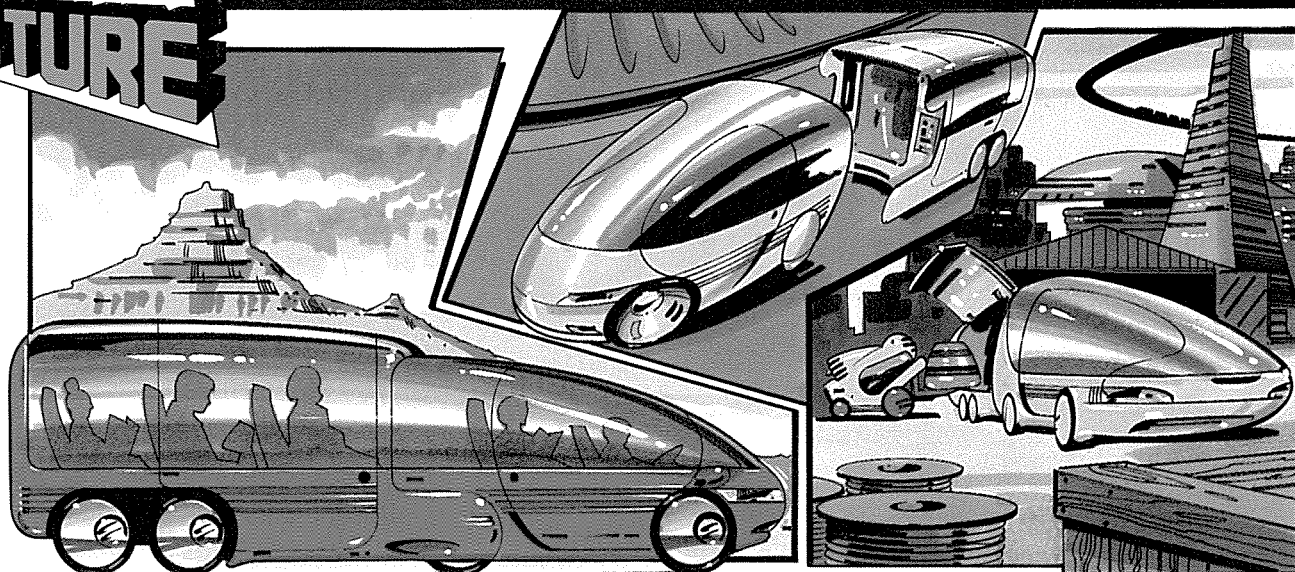
undamaged after a low-speed impact are now common. But some plastics lack strength. To toughen them, tiny fibres of another substance can be mixed in, producing what is known as a composite. For a number of years, Chevrolet Corvettes have had their

radiator. Already ceramics are being used in the more advanced engines (see FUTURES pages 105-106).

As oil and petrol become more scarce and air pollution grows, alternative fuels are being sought, and the possibilities of hybrid electric/diesel cars explored.

INTO THE FUTURE

THE 'TWO-IN-ONE' CAR



▲ The drivers of tomorrow will have a small car for city driving and a larger, roomy one for long journeys – simply by adapting a single vehicle.

▲ Both front and rear sections could be driven independently as three- and five-seaters respectively. But the two could also be combined into one large vehicle.

▲ The two sections will be linked electronically, with the front car acting like the command module of a spaceship. The car could be used to carry freight.

■ PORTABLE BRIDGES

■ BLAST WALLS

■ INSTANT HELIPADS

ARMY ENGINEERS

THE MILITARY ENGINEER IS the armed forces' unsung hero – a fighting soldier, a combat engineer and a specialist craftsman. Whenever a river or ravine must be spanned, a mine laid or enemy minefield 'swept', the engineers will be there, deploying the latest in portable, hi-tech equipment.

Paratroopers, among them engineers, swooping in at night on an enemy area where they have to mount an attack across a river, bring with them Air Portable Bridges (APBs). These are pontoons (flat-bottomed boats), light enough to be carried in an aircraft, that are bolted together to form a bridge or a ferry.

The APBs are loaded on to the aircraft on large, inflated cushion pallets with their own parachutes. The pallets are designed so that

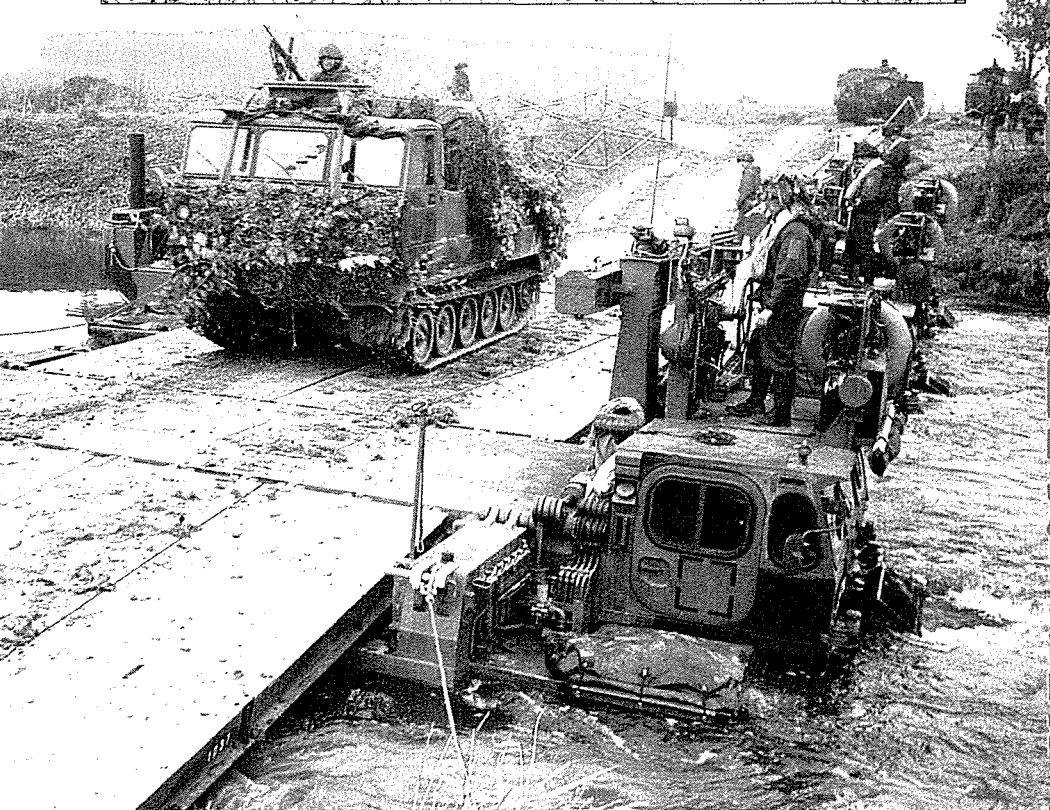
Royal Engineers of the British army roll a section of a Class 30 repair mat – used to repair or rapidly make runways – on to a recovery vehicle.

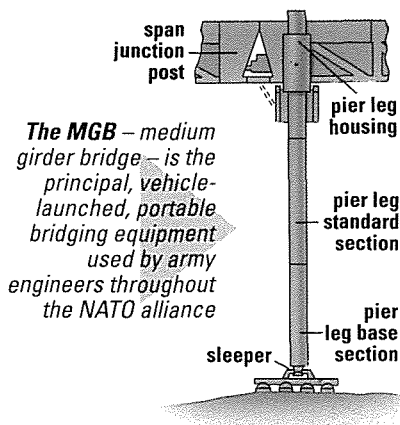


Photographic Section, Royal School of Military Engineering

dshead/TRH

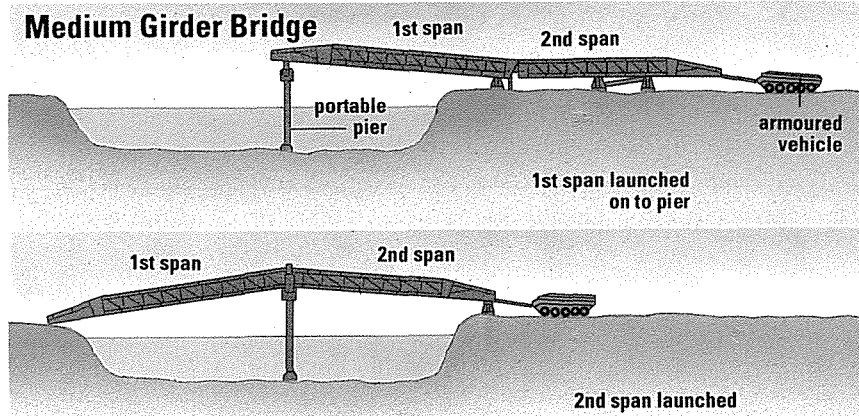
The M2 – a wheeled vehicle that can float and propel itself in water – is used both for bridging and ferrying heavy armour.





The MGB – medium girder bridge – is the principal, vehicle-launched, portable bridging equipment used by army engineers throughout the NATO alliance

Medium Girder Bridge



Mark Franklin

A US army AVLB – Armoured Vehicle Launched Bridge – is based on the M60 Main Battle Tank. It can launch its folding ramps across a 23-metre gap while shielding the crew from gunfire.

place ahead of the engineers, as paratroopers cross the river in lightweight-alloy craft and engage the enemy. The engineers guide the APCs aboard, one at a time, then ferry them over to support the forward line of battle. When the last APC is across, the engineers have to dismantle the raft, sometimes under fire, so that the helicopters can haul the sections out.

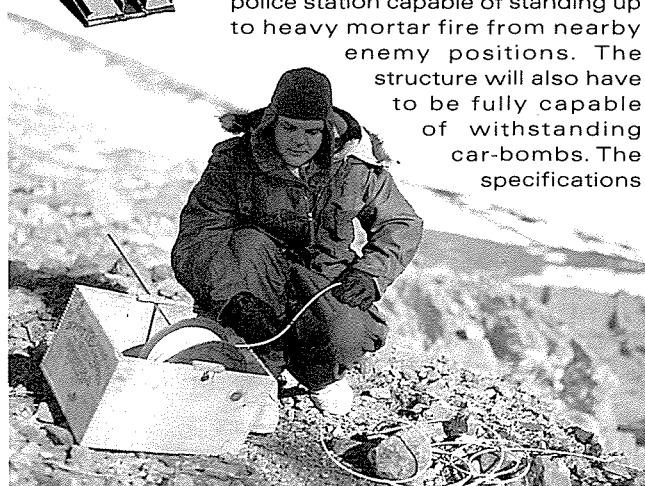


Building work

In places where the army is helping to keep the peace, military engineers replace civilian engineers for building and repair jobs. For instance, they might have to build a brand new police station capable of standing up to heavy mortar fire from nearby enemy positions. The structure will also have to be fully capable of withstanding car-bombs. The specifications

when they hit the ground the inflated sections burst, cushioning the load from the force of the drop. Each load is always marked with cy-lumes – chemically activated light markers that glow different colours in the dark – to enable the engineers to identify the various items.

Engineers are fully trained in the safe handling of explosives. Bridge demolition, for instance, is an aspect of their work, along with mine-laying, mine sweeping and the defusing of unexploded bombs.

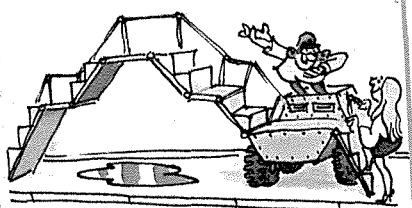


DOD/TRH

Just amazing!

INSTANT BRIDGE

THE CHIEFTAIN AVLB CARRIES A SET OF FOLDING RAMPS THAT CAN EXTEND TO FORM A 23-METRE BRIDGE IN JUST FIVE MINUTES!



Paul Raymond

At first light the engineers call in heavy-lift helicopters, such as Chinooks, to ferry the APBs to a strategic point close to the intended river crossing. Under cover of night, four-wheeled-drive vehicles tow the sections down to the river.



Assembling the APB

For the purposes of this operation, the engineers assemble the APB sections in the river into a raft capable of carrying Armoured Personnel Carriers (APCs), which are like small, highly mobile tanks. They bolt the sections together fast, accurately and in silence. Then outboard engines are fitted, one at each corner.

The first wave of the attack takes

could include perimeter blast-walls with an outer shell of reinforced concrete slabs slotted into special steel columns. Near public roads it would have double blast walls, the gap being filled with concrete.

Heavyweight protection is needed for semi-permanent structures. When, however, engineers work in exposed positions they may sometimes have to rush up a portable Rapid Assembly Protection Wall to ward off attacks.

Temporary helipads can be rapidly assembled for emergency use in the field. They are usually sited in areas that have been scraped level, surfaced with a specialist material such as Tensar geofabric, and finally covered with crushed rock.



PITSTOP

A TYPICAL FORMULA ONE motor race will cover about 300 km and take over one and a half hours, but the winning driver may well be decided during those crucial few seconds that his car is standing still – in the pitstop.

The pitstop is an essential part of motor racing and is carried out in a special lane that runs off the main track. It is where the car pulls in for tyre changes, minor electrical adjustments or even major structural repairs. An expert team of mechanics can change a complete set of tyres and have the car back in the race in less than ten seconds – possibly the crucial difference between victory and defeat.

With today's highly specialized racing tyres – known as slicks – it is routine for a car to make at

least one pitstop to change tyres during a race. Racing slicks are very different to normal car tyres. They are usually smooth, with no tread pattern, and maintain their grip by 'burning off' their soft rubber and depositing it on the track. This means that they wear out very quickly; the more powerful the car and the hotter the conditions, the more often the tyres need changing. A tyre will only be at its best for perhaps a handful of really hard-driven laps before it starts to lose its slight edge, so changes will be needed.

Qualifying laps

Special qualifying tyres are used the day before the race to decide starting line-ups on the grid – the fastest qualifier starts at the front and so on. The qualifying tyres will complete

Nigel Mansell has his wheels changed during practice. A portable computer screen gives drivers details of the fastest qualifying times and the race leaders (inset, left).

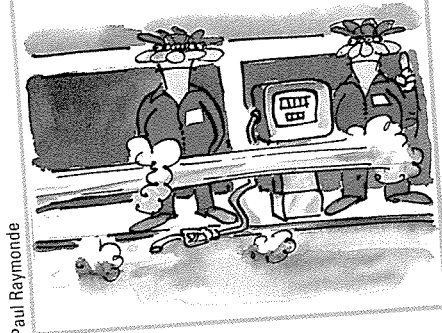
Vandystadt/Allsport



Just amazing!

QUICK STOP

AMERICAN DRIVER BOBBY UNSER HAD HIS CAR REFUELLED DURING THE 1976 INDIANAPOLIS 500 RACE IN JUST FOUR SECONDS - FASTER THAN IT TAKES TO READ THIS SENTENCE!



Paul Raymond

are faster, as soon as possible. Similarly, if the driver is using slicks when it starts to rain, he will want to switch to rain tyres as soon as he feels that he is losing grip. Whatever the reason for a tyre change, it must be done as quickly as possible. Two laps before a car makes a pitstop, the driver alerts his team of mechanics via his short-wave radio system



Pit procedure

Before each race, the mechanics lay out a distinctive trail of coloured tape leading to the point where they want the car to stop. When it pulls up, they spring into action. The team may consist of up to 20 men: three mechanics per wheel, two quick-lift jack operators, a time-keeper, lap-scorer and signallers.

Each one has a specific job to do. Of the three men at each corner, one removes the wheel using a high-

speed pneumatic spanner, another lifts off the wheel and the third man puts on the fresh wheel. During the stop, the driver is in contact with his chief mechanic or team manager through their radio headsets. With the roar of the engine and the whirring of the air-powered spanners, it would be impossible to communicate by any other means.

As soon as the new wheels are bolted in place and all four corner teams signal that they have finished, the jacks are lowered and the car is off on its way back into the race. A smooth tyre change can be completed in seven or eight seconds; a tricky wheel nut or loose wire could cost the driver precious minutes.



Emergency repairs

All sorts of emergency repairs can be carried out in the pits, ranging from a replacement visor for the

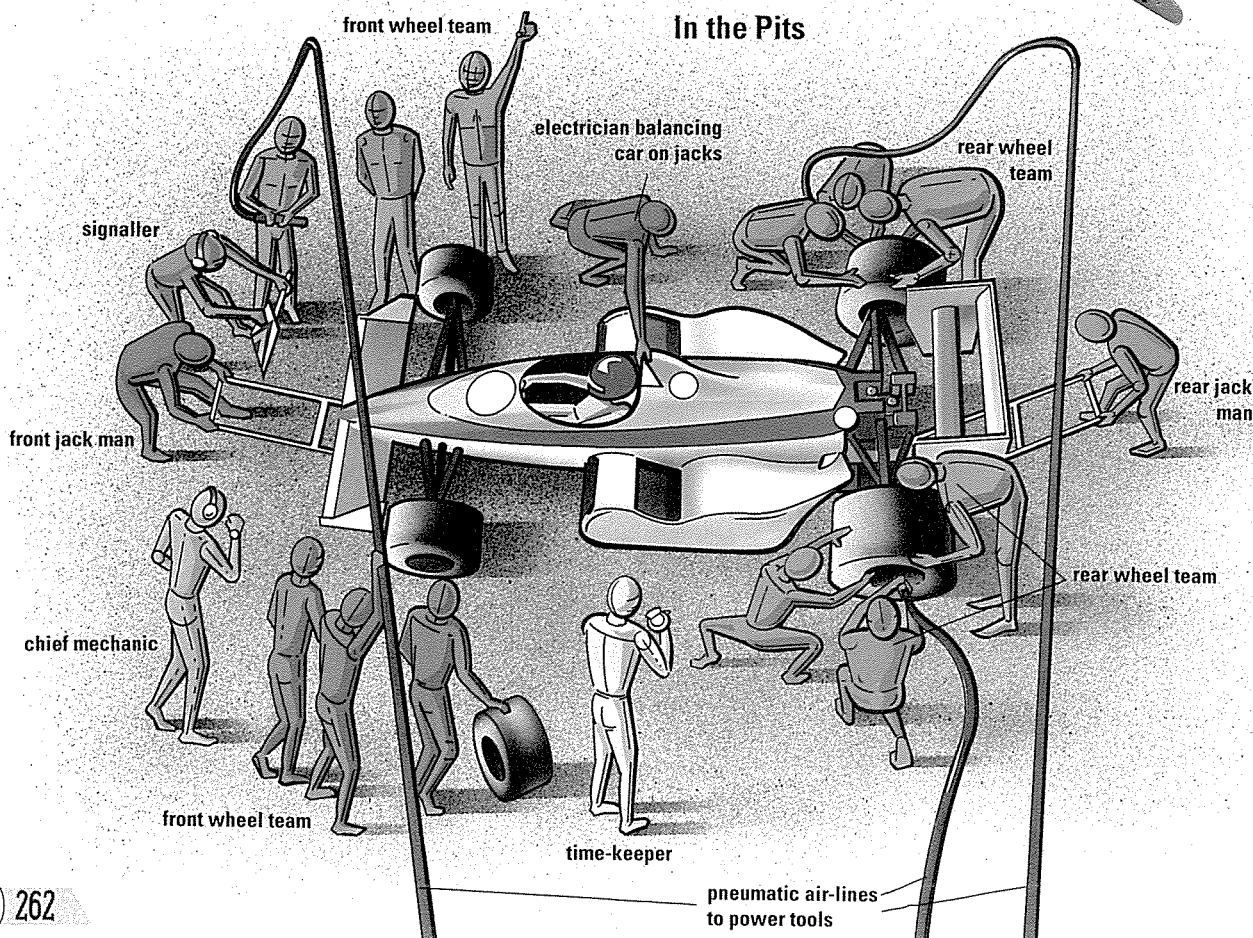
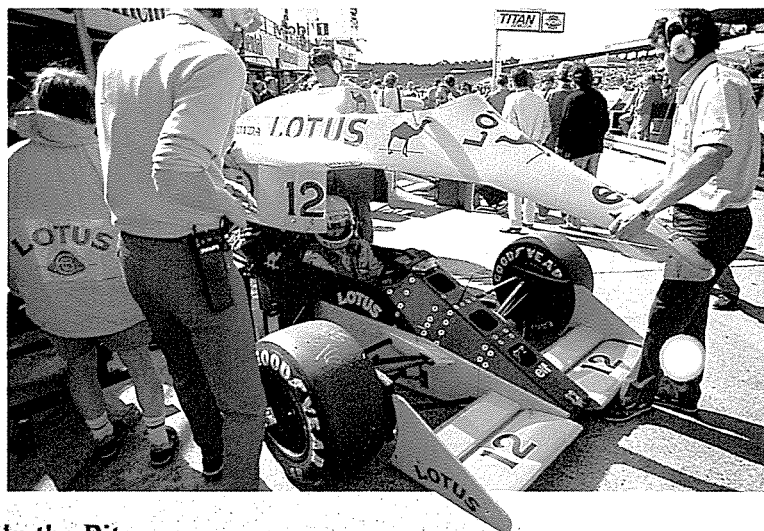
Tailade/Colorsport

perhaps one or two laps to get fully warmed up, then do one really fast lap to set a qualifying time, followed by one slowing-down lap, after which they will be discarded.

Another situation when tyres need changing is if the track gets wet because of rain, or alternatively dries up after a wet start. In wet conditions, cars use special 'rain tyres' that have a tread pattern similar to normal road tyres. This helps them dispel surface water to stop the car from aquaplaning - skidding on a thin layer of water.

If it has rained before a race, the track will be wet at first but may dry up later, so the driver will want to change to dry-weather slicks, which

A bodyshell replacement for a Lotus during the German Grand Prix in 1987. The team mechanics keep enough spare parts to replace a whole car if necessary, and bodywork repairs such as this one can be done in a matter of seconds - any longer and the driver loses all hope of winning.



Simon Critchley



driver to fitting a new nose cone on the front of the car. All teams carry at least one spare car and enough body panels to rebuild a whole car if necessary!

One routine pit stop task which has recently led to controversy and danger is refuelling. Early cars could not carry enough fuel to power the vehicle around the track for the entire race. Each driver had to stop to fill his fuel tanks at least once, sometimes twice, during a particularly long race.

Zoom Photographic Ltd

Zoom Photographic Ltd



Racing tyres are known as slicks. They are smooth and do not have tread patterns like normal road tyres.

Wet weather tyres have treads that disperse surface water and help the car maintain its grip in the rain.

start of the race and able to build up a fast time before stopping to refuel. The techniques of refuelling were refined so that the least possible time was spent in the pits. In 1994 a dramatic explosion in the pits when the Bennetton car was refuelling led to an inquiry into refuelling equipment and led many teams to rethink their fuel strategy.

By the late 1980s fuel efficiency had increased to the point that a vehicle could carry enough fuel for an entire race. However, this soon led to other problems.

Cars were so heavily laden with fuel at the start of a race that they would scrape the ground on the slightest bump in the track surface.

Compoint/Colorsport

This meant that cars had to be fitted with metal studs to protect their underside and these produced great showers of sparks when they struck the ground.

The weight of fuel also made the vehicle perform relatively sluggishly at the start of the race and many drivers complained that they were unable to exploit an early advantage due to poor acceleration.

As a result racing teams returned to refuelling during a race. This meant that the car was lighter at the

Onboard computers

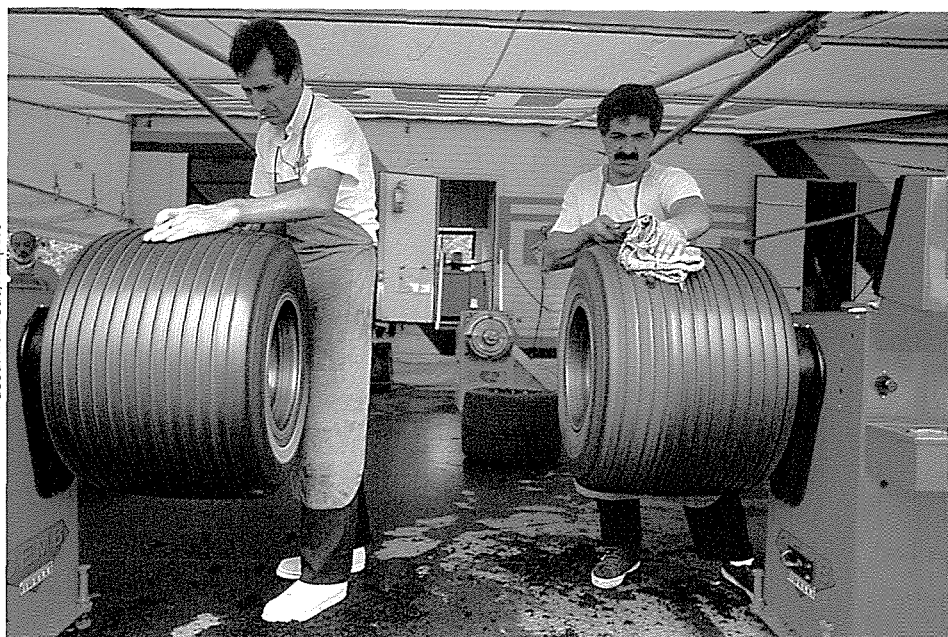
However, the car's computer is now considered an essential piece of equipment. Apart from fuel read-outs (which are usually correct), the computer can automatically adjust the suspension, so that the car maintains a constant height off the ground, whatever load it is carrying. As the race progresses and fuel is used up, the car becomes lighter and tends to rise higher off the ground, lessening its road-holding abilities. But the computer calculates the weight loss and relaxes the suspension.



Pascal Rondeau/Alisport

'Electric blankets' are used to get replacement tyres up to the optimum racing temperature required according to weather and track conditions.

Tyre technicians cutting treads into slicks. During a Grand Prix race meeting the cars may use up to 1700 tyres, of which 600 could be rain tyres.

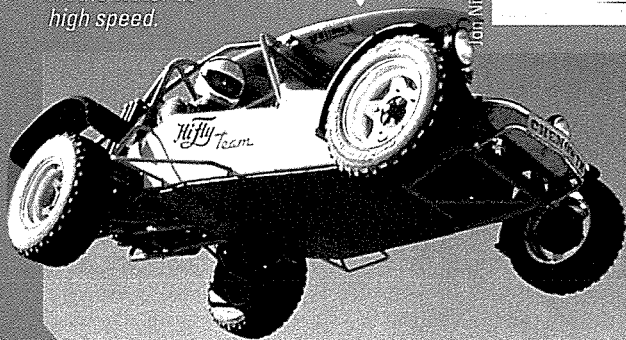




Vandystadt/Allsport

Jet skis are great fun, but they are used in serious races too. Riders wear motorcyclist's protective clothing in case they should hit the water at high speed.

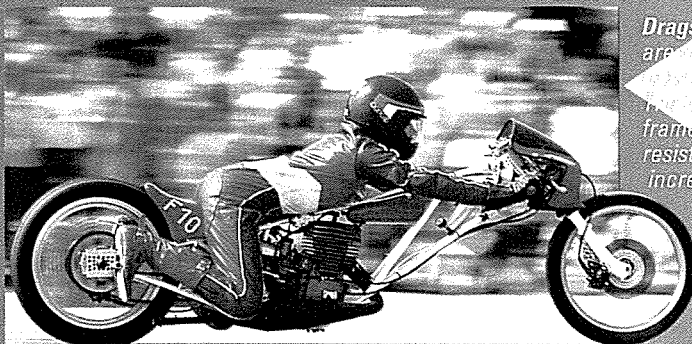
Dune buggies are designed to be driven over sand, so they are ideal for racing in desert rallies.



Jar, Nicholson/Allsport



The Paris-Dakar rally is raced over 11,000 km, mainly in Africa. This DAF truck was pulled out of the race in 1988 after one of the early drivers killed. The race has now been severely curtailed, with fewer entrants than before for safety reasons.



Dragstar motorcycles are very different to other machines. Their low-slung frame helps reduce air resistance and so increases speed.

S Compamy/Colorsport

Kenyan tribesmen watch the latest high-powered Toyota trucks in the shadow of Mount Kilimanjaro during the Kenya rally. The trucks cross some of the world's most spectacular scenery, but rarely have time to take in the view at speeds of 150 km/h.



R Klein/Sipa Sport/Colorsport

Snow scooters are used for getting around ski slopes quickly. Powered by motorcycle engines, they are capable of speeds of up to 50 km/h.



Vandystadt/Allsport

M Montague/Moto Journal/Colorsport

A motorcycle and sidecar at the start of the Pharaoh's Rally in 1988. This race around Egypt has separate sections for cars, trucks and motorcycles.



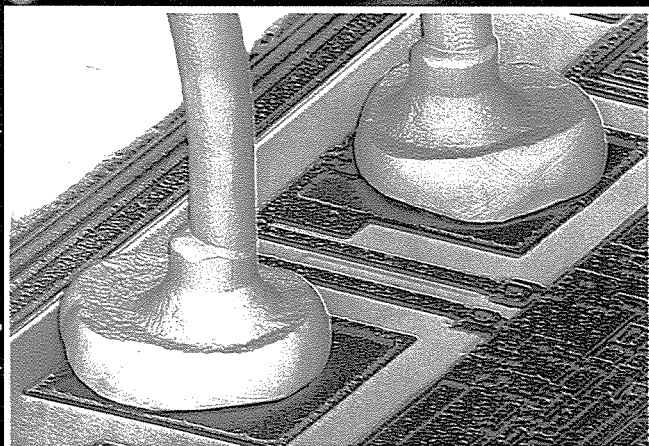
SILICON

TRANSISTOR

MICROCHIP

SEMICONDUCTORS

Dr Jeremy Burgess/Science Photo Library



SEMICONDUCTORS HAVE revolutionized our lives. These materials have made it possible for scientists to devise first the transistor and then the microchip, vital components found in today's electronic machines.

Materials that conduct electricity easily are known as conductors. They are mostly metals, although one non-metal, carbon, is an excellent electrical conductor.



Conductivity

All materials conduct electricity to some extent, but conductors do so one million million million times better than non-conductors such as plastics and ceramics.

In between these two extremes there are semiconductors, which conduct electricity better than plastics but less well than metals and have properties that lie between those of a conductor and a non-conductor.



Heat treatment

One important way in which a semiconductor differs from a conductor is its reaction to heat. When the temperature of a conductor increases, less electric current flows because its resistance is higher. However, heating a semiconductor has exactly the opposite effect - more electricity flows through the material.

Semiconductor materials include the elements germanium and selenium and the compound lead telluride.

Microchips are etched onto silicon materials - usually silicon. Thousands of tiny circuits exploit the electrical structure of the semiconductor. The minute circuits and connections (inset) have to be checked under a microscope.

But the semiconductor material that is mostly widely used today is silicon, the element whose name is now used to describe the most important part of the electronics industry - the manufacture of integrated circuits, or silicon chips.

To understand how a semiconductor works, it is necessary to know what an electric current is. In a metal, each atom has some electrons that are easily released. So there are always a number of electrons that are free to wander among the lattice-work of atoms. If a source of electricity, such as a battery, is connected across a metal wire, the 'free' electrons, which are negatively charged, are attracted to the positive terminal of the battery and there is a flow of electrons along the wire. This flow of electrons is what we call an electric current.



Free electrons

In a non-conductor the atoms are constructed in such a way that there are no 'free' electrons available, and so connecting a non-conductor to a battery does not produce an electric current. In a semiconductor, the atoms are very like those of a non-conductor. However, a few electrons do have enough energy to break free from their atoms and become available for carrying electricity. Heating

ZEFA



such a material puts more energy into the system and more electrons break free, which is why the conductivity of a semiconductor increases as its temperature increases.

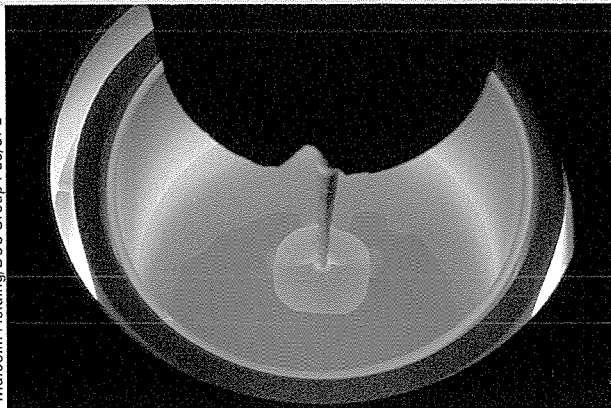
As in a metal, free electrons in a semiconductor move towards the positive terminal. This results in what is known as n-type conductivity. At the same time there are spaces, or holes, left in the atoms. These behave in a more complicated way, but they can be thought of as having a positive charge and drifting in the opposite direction to the electrons, a phenomenon known as p-type conductivity. The total electric current that flows through the semiconductor is the combined effect of the electron current and the hole current.



Pure semiconductors

Pure, or intrinsic, semiconductors are not particularly useful, because at normal temperatures they only conduct very tiny amounts of electricity. However, the conductivity of a semiconductor can be greatly increased by adding a tiny amount of another element as an impurity. Two kinds of semiconductor can be produced in this way. For example, when silicon is 'doped' with a small amount of phosphorus, some of the silicon

Malcolm Fielding/BOC Group PLC/SPL



A silicon chip is made from a silicon crystal. A crystal 'seed' is suspended in molten polysilicon. It is rotated and, slowly, a crystal grows, reaching 75-100 mm in diameter and up to 1 metre in length. The thin chips are cut from this.

atoms become replaced by phosphorus atoms. Phosphorus has more electrons available than silicon and this results in an n-type semiconductor with extra electrons. Antimony can also be used to make an n-type semiconductor. Aluminium, on the other hand, has fewer available electrons than silicon. Doping silicon with aluminium therefore produces a semiconductor with extra holes; that is, a p-type semiconductor.

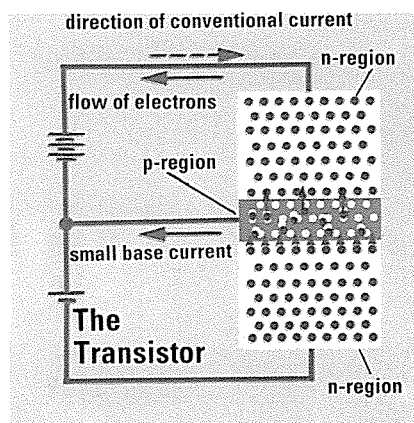


Rectifiers

Placing an n-type semiconductor against a p-type semiconductor forms a p-n junction. This is the basis of a device known as a rectifier, which is used to convert alternating electric current into direct current. Placing two p-n junctions back to

back creates a transistor, of which there are two possible types – p-n-p and n-p-n. Transistors can be used as electronic switches or for amplifying electrical signals.

These and other electronic devices can be created on the surface of a small piece of silicon by 'doping'

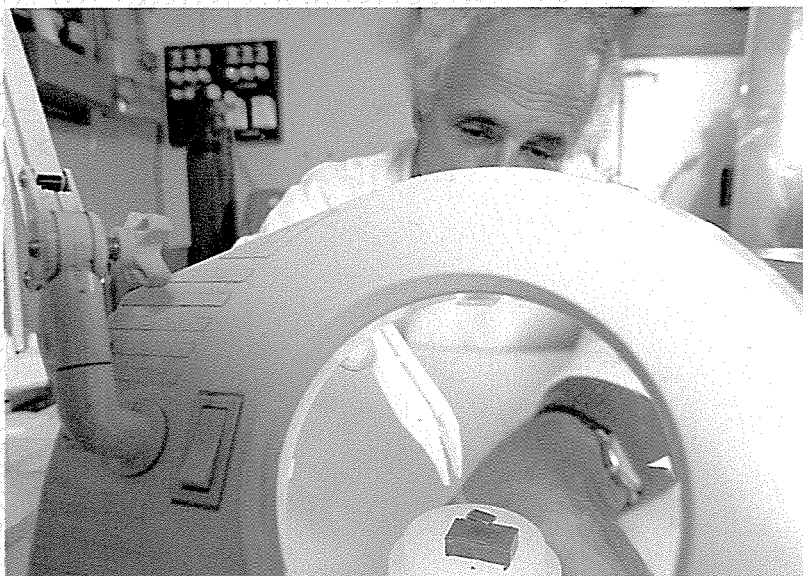


Mark Franklin

In a transistor, semiconductor layers are arranged so a small current in the P-layer controls a larger current in the device.

selected areas with the appropriate impurities. Adding suitable metal connections creates an integrated circuit, known as a silicon chip. Semiconductors are also being used to create very small, stable lasers for use in optical-fibre telecommunications systems.

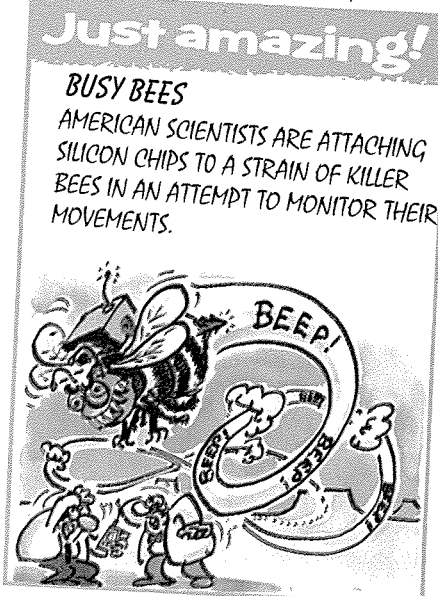
SUPERCONDUCTORS



Ivaldi/Jerrican

As the temperature of a material approaches absolute zero (0 K or -273°C), its resistance to electrical current drops to zero and it becomes a superconductor. Mercury, for example, becomes a superconductor below 4.2 K, lead superconducts below 7.2 K and niobium-germanium alloy superconducts below 23.2 K. A key test of superconductivity is that a superconductor floats in a magnetic field (see above), a phenomenon known as the Meissner effect. Silicon chips whose circuits are made of superconducting materials will be able to carry electrical signals very rapidly, meaning that com-

puters would be able to process information faster than ever before. However, it is difficult to cool materials to such low temperatures and the problems increase as temperatures get closer to absolute zero – 0 K is actually impossible to reach. But scientists have recently discovered complex materials containing the element thallium that superconduct at the much higher temperature of 125 K. In the future, some materials may superconduct at around 200 K (about -17°C). However, there are still problems, and it remains to be seen if any of these 'warm' superconductors will prove useful.



Paul Raymond



- POLYMERIZATION
- SHAPING PROCESSES
- ARTIFICIAL FIBRES

FANTASTIC PLASTIC

PLASTICS ARE AMONG THE most versatile of modern materials and in many cases are better than natural ones. They are now used in place of wood and metals in a vast range of products and household equipment. Items such as photographic film and non-stick surfaces could not be made from anything but plastic.

When we describe something as being plastic we mean that it can be moulded or formed into any shape. Plasticine, for example, is a truly plastic material. On the other hand, many of the materials that we know as plastics are hard and inflexible. Such plastics can be softened and moulded by applying heat, but so too can other hard materials, such as glass and metal.

Carbon atoms

The thing that distinguishes plastics from other synthetic (man-made) substances is the fact that their molecules are based on long chains of carbon atoms. Most are made of chemicals obtained from crude oil and natural gas, such as ethylene or ethene propylene, butylene, benzene and methyl alcohol. Ethylene is used to make a range of plastics, including polythene polyvinyl chloride (PVC), polyvinyl acetate, polystyrene and acrylic. Such carbon-containing chemicals are known as organic chemicals, because they were first discovered in living organisms.

Plastics can be divided into two main groups - thermosoftening plastics (also called thermoplastics)

In extrusion moulding, plastic is heated and forced by a rotating screw through a mould of the required shape.

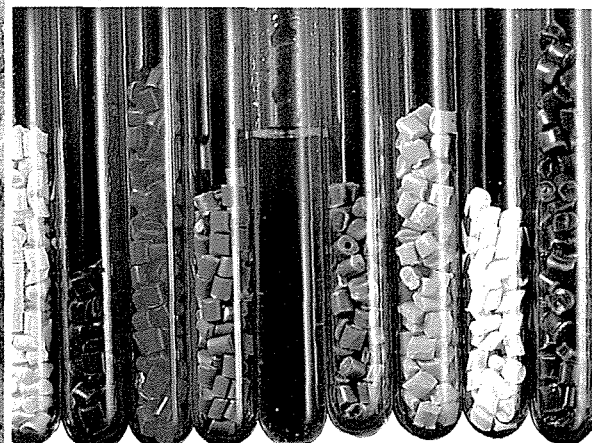


and thermosetting plastics. 'Thermo' comes from the Greek word meaning 'heat' and these two terms describe what happens when plastics are heated. A thermosoftening plastic softens when heated and becomes hard again when cooled. This is because its long-chain molecules become flexible and capable of sliding over each other. Thermosoftening plastics, such as polythene, can be shaped and reshaped many times.

Softening occurs at different temperatures in different plastics. For example polythene begins to soften when dipped in boiling water. Nylon remains hard in boiling water but can be softened by heating it over a flame. PTFE remains hard until it reaches a temperature of just over



Crude oil is divided into many components, or fractions, by distillation. One of these – naphtha – contains the chemicals used in the manufacture of plastics. Plastic for moulding is supplied in the form of powder, liquid, paste or granules (below).



In an oil refinery, petroleum is heated and fed into a 'fractionating tower' where the various components separate out at different levels according to their boiling points. The gases evaporate and rise to the top, while the heavier oils are collected at the bottom.

Plastic pipes, curtain rail and thick plastic sheets are made in this way

- Calendering is used to make thin plastic sheets – hot plastic is squeezed between a series of rollers

- Injection moulding is a widely used process whereby hot plastic is forced through a nozzle into a mould. The plastic fills the mould completely and forms a solid object, which is removed by separating two halves of the mould. This produces mouldings of very high quality and great accuracy. It is used to make objects such as vacuum cleaners, bottle crates and protective helmets.

- Compression moulding, in which hot plastic is squeezed into shape by bringing the two halves of the mould together, is used to make objects such as bottle tops and toilet seats

- Blow moulding is used for hollow objects such as plastic bottles. A piece of hot plastic tubing is placed between the two halves of

Paul Brierley

Ethylene, a chemical derived from petroleum, is turned into polythene by polymerization. This transforms small molecules into long chain molecules.

created by the polymerization of simple organic chemicals. When a thermosetting plastic is heated, chemical reactions take place – cross-linking bonds form between the long-chain molecules, holding them together rigidly in a three-dimensional network. If a thermosetting plastic is heated, the only result is that more cross-links form and the plastic becomes even more rigid.



Heat-resistance

Thermosetting plastics are used to make heat-resistant objects, such as light fittings, saucepan handles and kitchen worktops. They include such plastics as Bakelite (also called phenol-formaldehyde or phenol-methanal), polyurethanes, polyester resins and epoxy resins.

One of the most useful properties of plastics is the fact that they can be formed into almost any shape and can therefore be fashioned into a wide range of different objects. Several forming methods are used:

- Extrusion is the simplest. Hot plastic is forced through a specially shaped hole, or die, to form a long piece of plastic with the same cross-section all the way along its length.

Just amazing!

TIME FOR A CHANGE

IN THE FUTURE, CLOTHING MANUFACTURERS WILL BE ABLE TO CREATE CLOTHES FROM SYNTHETIC FIBRES THAT CHANGE TO WHATEVER COLOUR THE WEARER WANTS



Paul Raymond

330°C, which is why it can be used for non-stick surfaces on pans.

A thermosetting plastic, on the other hand, can be shaped only once – at the time that polymerization takes place. This is the process of joining up short molecules to form long ones. All plastics are polymers



Chemical Design Ltd, Oxford/SPL



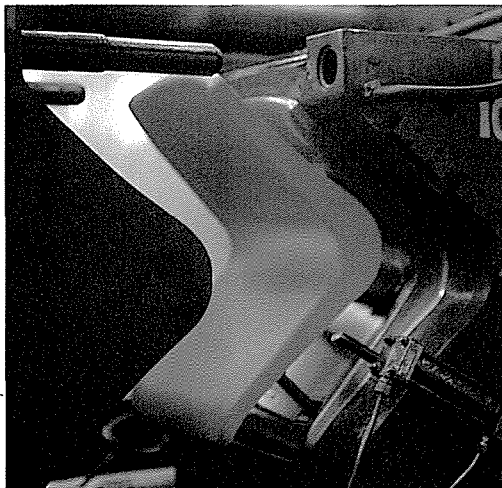
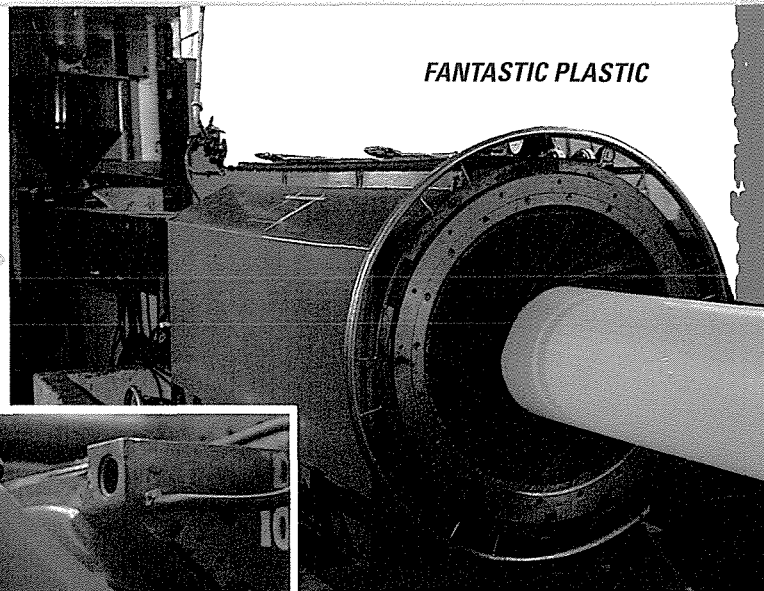
the mould, which are then pushed together to trap a section of tube inside. Air is then blown into the mould, forcing the tube to take the shape of the inside of the mould

- Vacuum-forming uses air pressure in a different way. A sheet of hot plastic is held in a frame and pulled down on to a mould by suction. Acrylic baths, boat hulls, the linings of refrigerators and plastic egg boxes are made in this way

- Rotational moulding is the technique used for large containers with thick walls, such as water tanks and dustbins. Plastic granules are poured into a mould that is rotated on two axes at low speed. The mould is heated and the plastic melts, forming a skin that sticks to the inner surface. While still rotating, the mould is cooled by air or water spray or a combination of both. Rotationally moulded products include fuel tanks, toys, surfboards and storage tanks.

All thermosoftening plastics can be made into fibres – the long chain molecules simply align themselves in one direction. Artificial fibres are generally harder wearing than

Polythene pipes are made in an extruder. Plastic granules are forced through a heated barrel by a revolving screw, which injects the softened plastic through a cylindrical die.



Plastic chairs are shaped by means of injection moulding – plastic is forced through a heated barrel into a steel mould.

Most plastic-shaping methods involve softening the material by heating before forcing it through a mould. Thermoplastics are easiest to shape because they stay molten while they are hot.

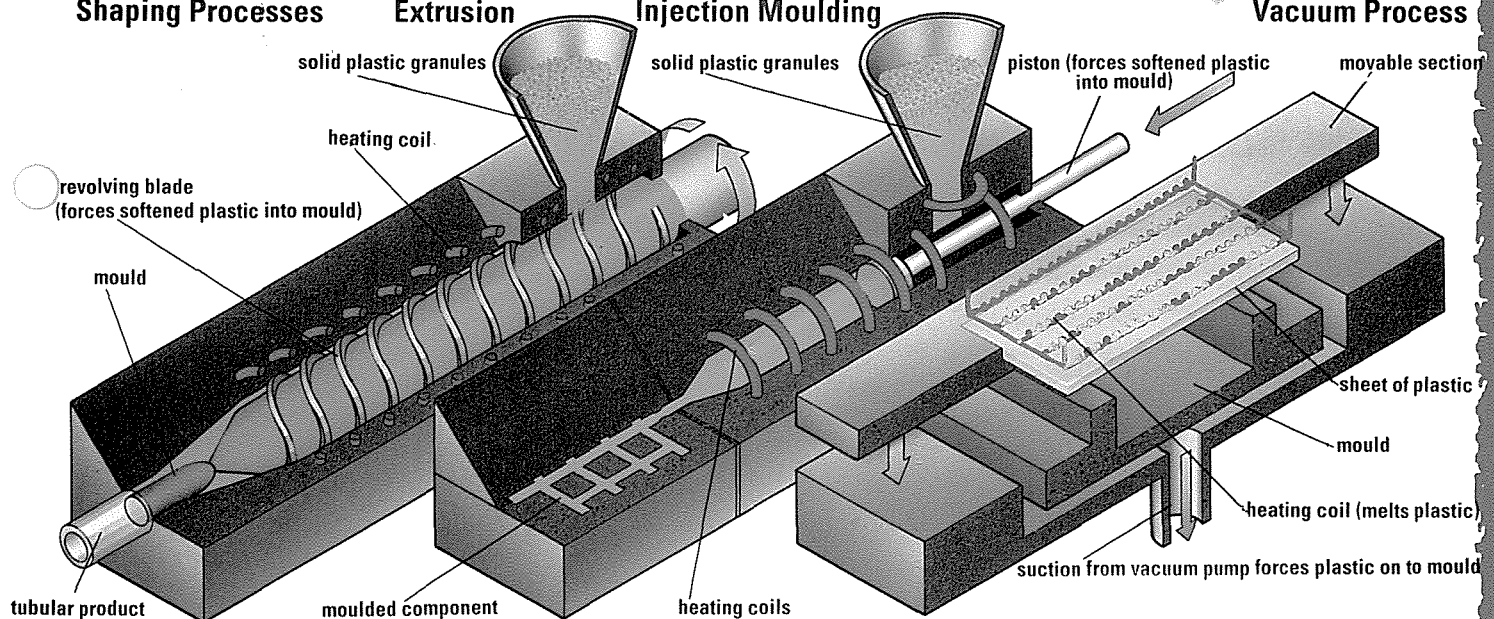
Ron Oulds/Robert Harding Picture Library

Shaping Processes

Extrusion

Injection Moulding

Vacuum Process



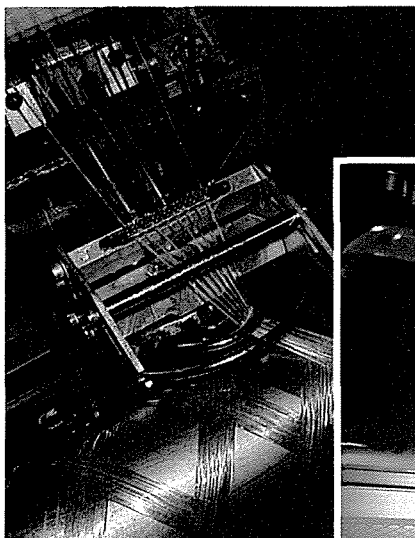
Calendering is a method for making sheeting by passing plastic through heated rollers. Plastics can be strengthened by adding fibreglass (left).

natural ones such as wool and cotton. Plastics such as polypropylene and nylon produce strong fibres that are widely used. Some thermosetting plastics are drawn out in the form of fibres, such as polyacrylonitrile ('acrylic' fibres) or copolymer, formed from acrylonitrile and vinylacetate.

Strong fibres

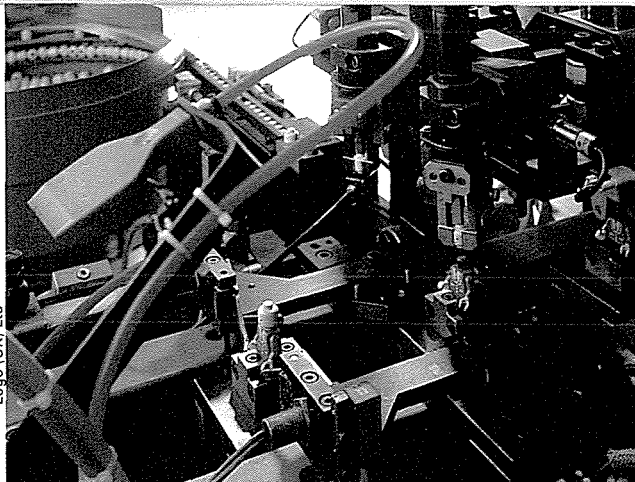
Among the strongest fibres are those that belong to a group known as aramids. These are derived from nylons (polyamides) and differ from other plastics in that they char rather than burn. They are immensely strong materials; the tough fabric Kevlar is based on aramid fibres and is used to make bullet-proof clothing.

Another, completely different



form of plastic is plastic foam. This is simply a plastic that has been filled with bubbles of air before being allowed to become solid. Polystyrene is commonly formed as a foam to make insulation panels and packing materials. Other plastics used to make foams include polyethylene and PVC. Polyurethane foams are employed in building and in the manufacture of furniture. A major drawback, however, is that

Lego (UK) Ltd



LEGO components are produced by pressure and vacuum moulding. It takes between 7 and 10 seconds to mould, cool and extrude one batch of LEGO pieces.

COMPOSITES

Plastics are often mixed with other materials to form what are known as composites. Chipboard, for example, is a composite formed from wood and urea-formaldehyde resin. A small amount of urea-formaldehyde is also mixed with wood fibres in the manufacture of paper towels. The resin holds the paper's fibres together, giving it extra strength when wet.

One of the most common composites is glass-reinforced plastic (GRP) or fibreglass. Polyester resin is reinforced with glass fibres woven into a mat or fabric to produce a very strong material that is used to make boat hulls, car bodies and aircraft seats. GRP is also used in the nose-cone of the supersonic airliner Concorde.

Asbestos, cotton and nylon can also be added to plastics to improve strength and heat resistance. The most widely used composite is carbon-fibre reinforced plastic (CFRP), made by embedding carbon fibres in an epoxy resin. Carbon composites are used to make sports equipment, artificial limbs and aircraft parts.

Plastic roads have foundations made of polystyrene blocks. These are covered with a thick sheet of plastic and capped by a normal tarmac road surface.

they give off potentially lethal, choking fumes if they catch fire.

Transparent plastics are made into lightweight, shatter-free substitutes for glass. Acrylic, sold under such trade names as Perspex and Diakon, is used to make aircraft cockpit canopies, secondary double glazing and lenses. It can also be coloured to produce such things as brake-light covers for cars.

See-through plastic

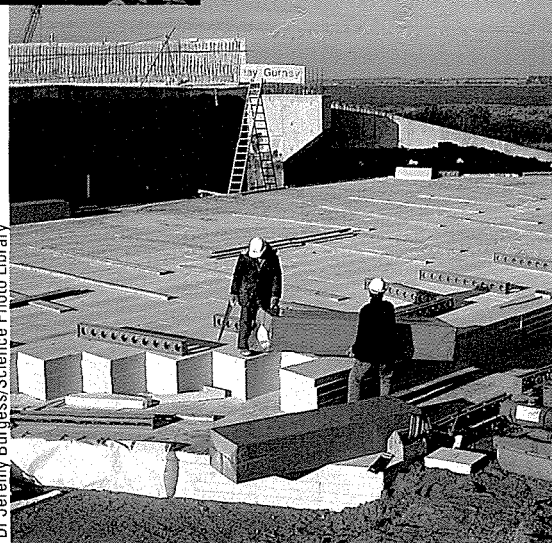
Polycarbonate is also transparent and is much stronger than acrylic. It is used to make riot shields, bullet-proof partitions in banks, and babies' bottles. Like acrylic, it can be coloured and used to make safety helmets and computer parts.

Plastics are used in liquid form to provide other materials, such as metal or paper, with a protective coating. Paints and varnishes often

contain thermosetting resins, which dry to give a very hard finish.

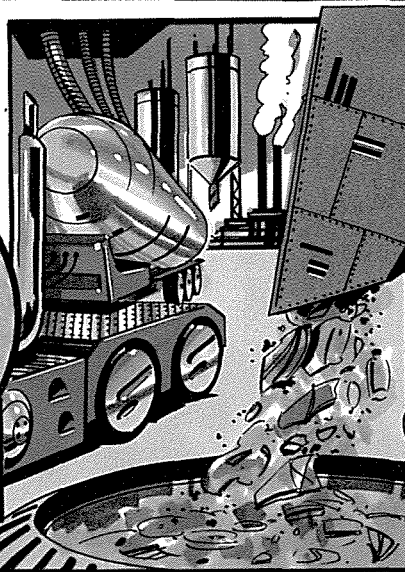
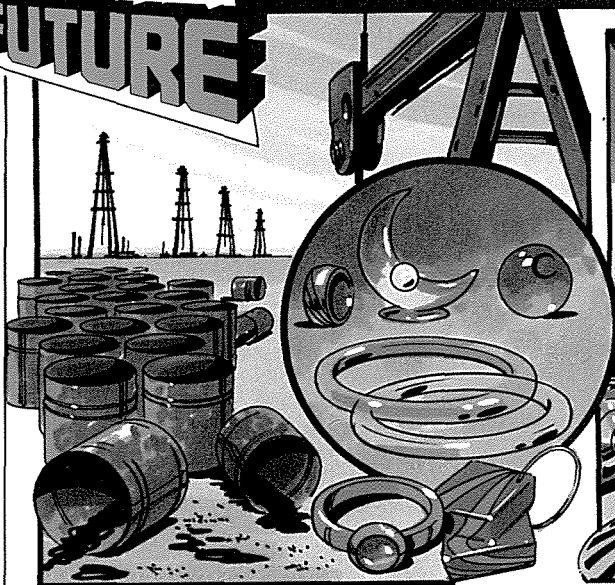
Some plastics are used as glues. They can be made soft and sticky by either heating them or dissolving them in suitable solvents. Solvent-based glues include polystyrene cement and rubber solution, which is used to mend bicycle tyres.

Dr Jeremy Burgess/Science Photo Library



INTO THE FUTURE

WHEN OIL RUNS OUT



▲ As the world's oil supplies begin to dwindle during the next century, making plastics from oil by-products will become too expensive.

▲ Manufacturers will have to use recycled packaging to an even greater degree, making raw materials go further and further.

▲ Eventually scientists will harness microbes to build new plastics from waste products, churning out new materials from a 'chemical soup'.

■ DEFUSING BOMBS

■ BODY ARMOUR

■ ASSAULT EQUIPMENT

COUNTER TERRORISM

AS BOMB ATTACKS shootings and political kidnappings become gruesome facts of life, the world's security forces are increasingly reliant on advanced technology to combat ever-changing terrorist tactics and weapons.

Some of the greatest advances in counter-terrorist technology have

Terrorist bombs planted in cars and on planes have claimed countless lives worldwide, despite improvements in explosive detection devices.

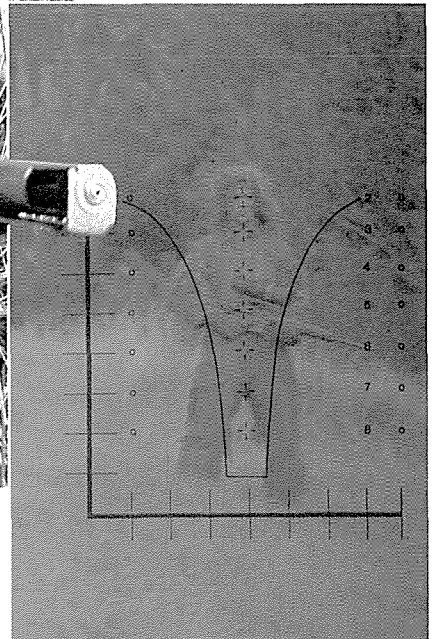


Rex Features Ltd





Image-intensification sights can be attached to rifles, enabling the soldier to see his enemy in the dark (below). The lens enhances low-level light by more than 85,000 times.



USMC/TRH Pictures

been in the area of advanced surveillance equipment. For example, long-range cameras, which can be mounted on the underside of a helicopter, are used for monitoring the movements of suspected terrorists. Cameras and rifles can also be fitted with image-intensifiers, which electronically amplify low-level light, allowing security forces to see their enemy at night. High-powered searchlights can also be attached to helicopters for night surveillance. These can pinpoint and illuminate a small area from high altitude, thus re-

baggage screening systems, using the latest X-ray technology, have reduced the likelihood of hijacking.

Machines that can detect explosives have also frustrated many terrorist actions. Most explosives emit vapour, which can be analysed by electronic 'sniffing' machines. However, more and more terrorist groups are using odourless plastic explosive, such as Semtex, which cannot be detected by sniffer dogs or by X-ray machines.

Armoured vehicles

Internal security (IS) vehicles are standard wheeled armoured vehicles, only with a number of different attachments added to make them suitable for operations in a counter-terrorist or riot situation. These can be water-cannon, 'cow-catchers' to re-

move barricades, searchlights, electrification systems to prevent a mob climbing on to the vehicle and tear-gas dispensers. IS vehicles are often modified to make them more suitable for an urban environment. For instance, they are given an extra door in the side to allow the crew to get out quickly in an emergency or are fitted with sloping roofs so that bombs thrown from rooftops will roll off.

Distant danger

Remote-controlled vehicles have been developed that enable the Ammunition Technical Officer (ATO) to remain at a safe distance while he locates, identifies and monitors a suspected bomb (all this is done via a TV screen). If he decides that the object is too dangerous to approach, he can attempt to disarm or destroy it by

Surveillance systems, with infra-red sensors, TV monitors and remote-controlled cameras, protect military and government installations from terrorist attack.

RADAR SNIPER-TRAP

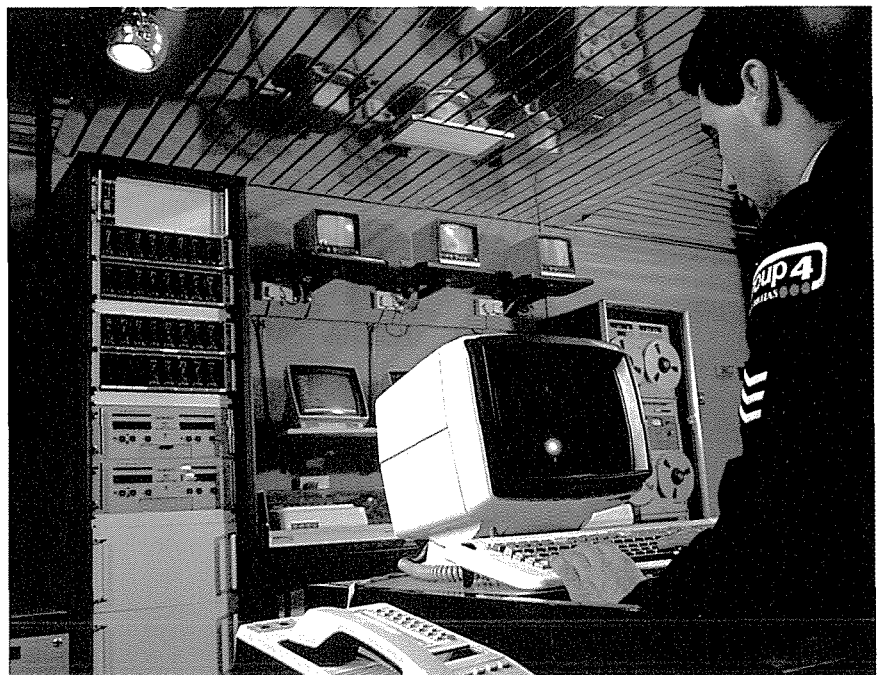
One of the most difficult things for a soldier to work out is the direction from which he is being shot at. This is particularly difficult in towns where shots tend to echo and re-echo around buildings. But a radar system called Claribel can indicate to within a 30° arc where the bullet was fired from. The equipment can be fitted on to armoured vehicles, or carried in a flak jacket. It detects missiles of all velocities except stones and bricks. The direction of fire is indicated on a simple luminous clockface display. The system can also indicate the positions of two separate snipers firing simultaneously.

ducing the threat of small arms fire. The searchlights can be fitted with a special filter to observe activities at night without a terrorist knowing the beam is directed at him.

Spy in the sky

Satellites are also used in the fight against terrorism. American satellites have been used to observe bomb factories in 'hostile' countries such as Libya, and to monitor illegal arms shipments to terrorist groups around the world.

At international airports, improved

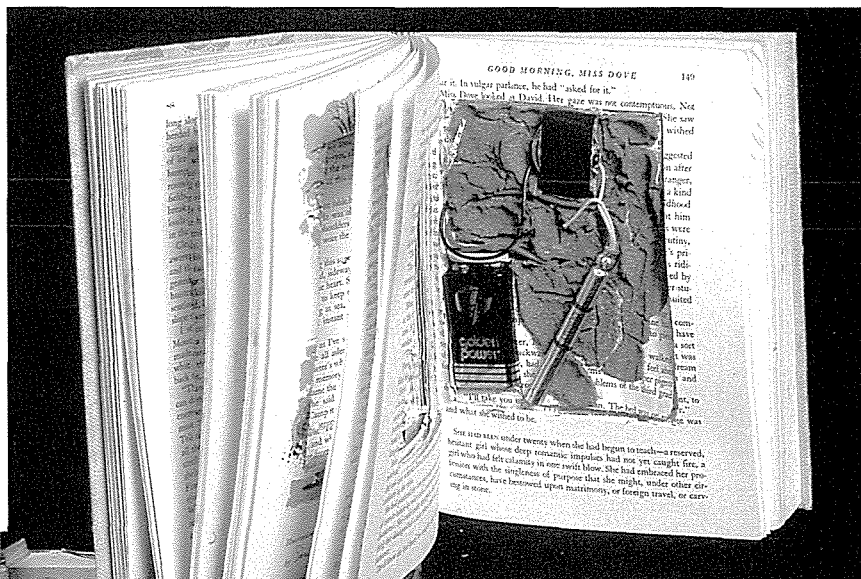


Group 4 Ltd



using the 'Wheelbarrow'. This is a radio-controlled device for defusing bombs, which has been developed and refined by the British Army since the start of the Troubles in Northern Ireland. The Wheelbarrow can be adapted to deal with different types of target. It has a closed-circuit TV camera and monitor, lights to illuminate the target and an automatic rifle that fires a 'disruptor' projectile at the bomb to break up its circuits and fuses. It also has a telescopic boom for examining bombs planted in inaccessible places such as petrol tankers – a favourite IRA target. With the latest additions it can even carry and automatically fire a variety of weapons used in riot, hostage or 'shoot-out' situations.

'The Pig' – the Humber 1-tonne armoured personnel carrier – was brought back into service as an anti-riot vehicle on the streets of Northern Ireland. As the IRA's weaponry grew more sophisticated, the vehicle was reinforced with extra armour plates.

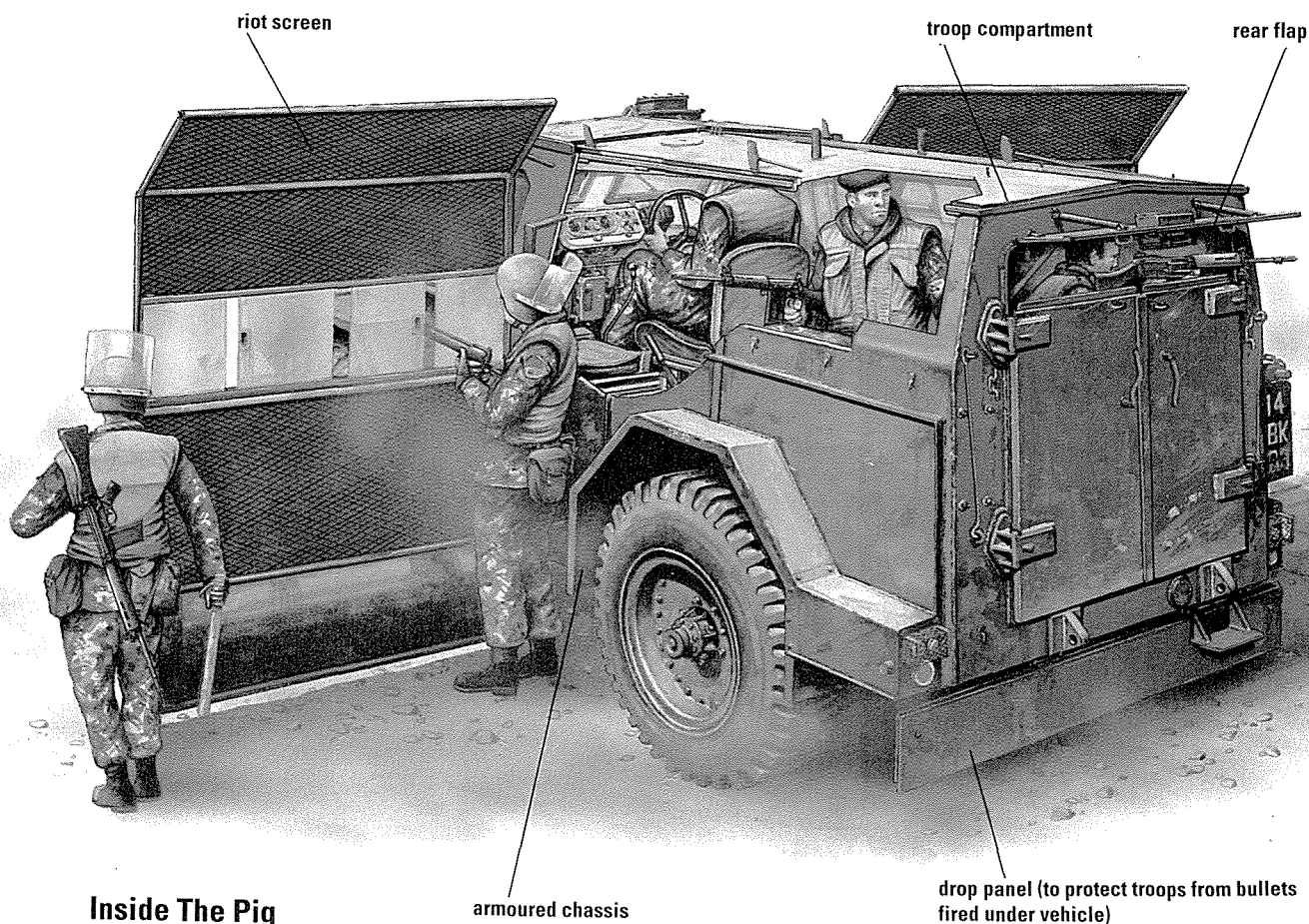


Gamma/Frank Spooner Pictures

Massive hauls of bomb-making equipment and arms have frustrated terrorist actions but even small amounts of explosive (above) can prove deadly.



On some occasions, the bomb-disposal officer will have to approach the suspected bomb himself, either to prevent blast damage or because forensic evidence is required. In such a case, he will wear an EOD suit, made of ballistic nylon, which is de-



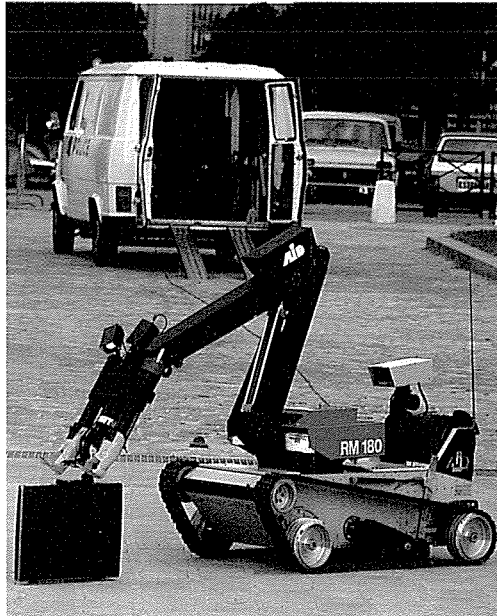
Inside The Pig

armoured chassis

drop panel (to protect troops from bullets fired under vehicle)



This radio-controlled bomb disposal vehicle is equipped with closed-circuit television and X-ray equipment to examine suspect packages (below).



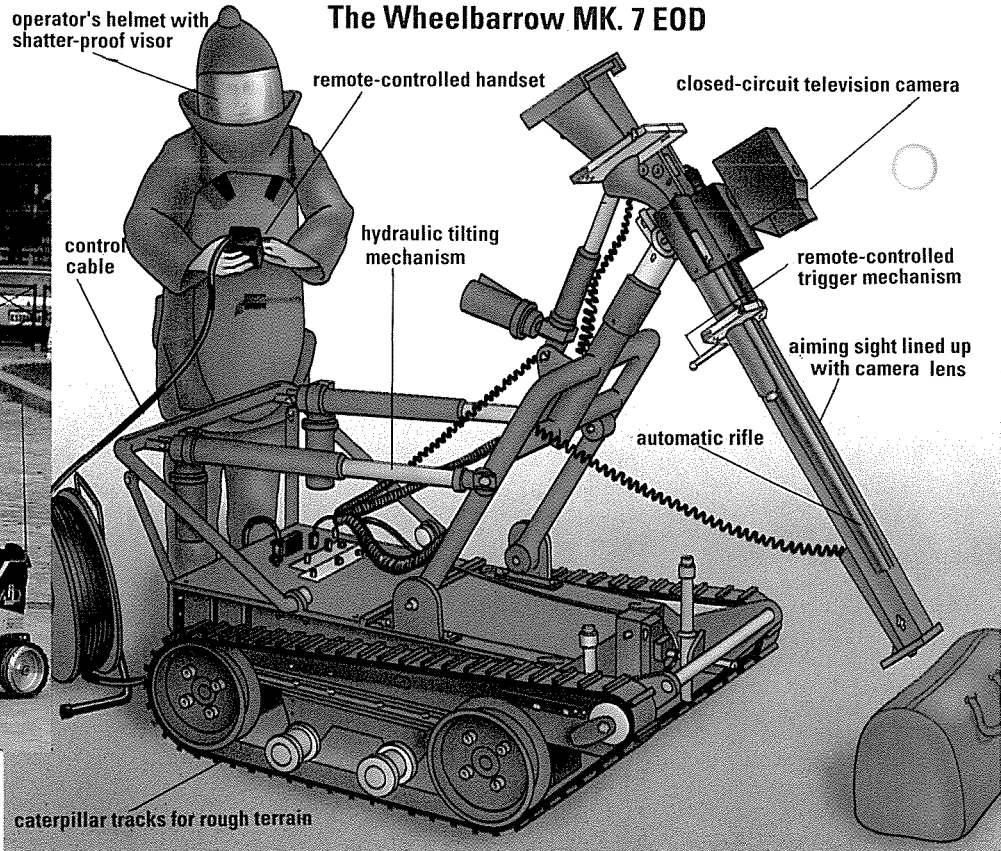
Labat/Lanceau/Jerrican/SPL

signed to give some protection against fragments, blast and flames during the disarming of improvised explosive devices (IEDs). The minimum requirement for such suits is that they withstand a 250 gm nail-bomb at a distance of 0.9 metres.

Bomb blanket

Security personnel can also be protected from the full blast of a bomb by covering the explosive with a bomb-suppression blanket. Made of fire-resistant ballistic nylon and Kevlar, the blanket reduces the pressure of an explosion.

Anti-terrorist squads such as the Special Air Services (SAS) have a wide variety of assault equipment at their disposal when called upon to intervene in a terrorist situation. One of



A bomb-disposal van contains a wide range of equipment, including bomb-protection suits and helmets, portable X-ray equipment, under-vehicle inspection mirrors, bomb-disposal tools and tripod-mounted lights.



AI Security

these, the stun grenade, first came to the public's attention in the October 1977 Mogadishu hijack in Somalia, when the SAS provided technical assistance (and stun grenades) to the German anti-terrorist squad GSG 9. They were also used in May 1980 by the SAS during the storming of the Iranian Embassy in London. The purpose of the grenades is to shock the terrorist into temporary inactivity and to distract him while entry is gained to the building or aircraft in which hostages are being held. The grenades produce one or more ear-splitting detonations and a blinding flash. Although stun grenades are designed to be non-lethal, their premature detonation could severely injure the thrower.

The general category of assault equipment also includes tear-gas (CS) grenades and launchers, sniper rifles, lightweight assault ladders,

grappling hooks and helicopters specially adapted for landing anti-terrorist troops.

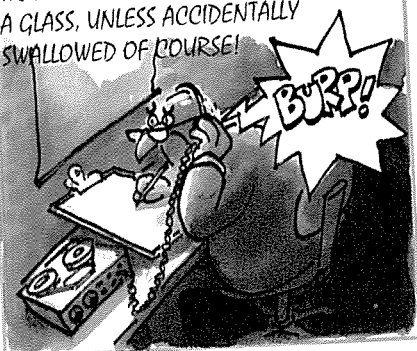
Eye-identification

Identification of suspected terrorists will soon be made easier by eye scanning. Every person has a unique and unalterable eye pattern. A retina scanner can identify a person by bouncing an infra-red beam against the back of the eye and reading the pattern of blood vessels. These scanners should soon help bring terrorists to justice.

Just amazing!

BITE ON A BUG!

AN EARLY COUNTER-TERRORIST BUGGING DEVICE WAS DESIGNED TO LOOK LIKE A COCKTAIL OLIVE. IT TRANSMITTED FROM THE BOTTOM OF A GLASS, UNLESS ACCIDENTALLY SWALLOWED OF COURSE!



Paul Raymond



STRATEGIC BOMBERS

LOW-LEVEL ATTACK

STEALTH

BOMBS AWAY!

WHEN MISSILES WERE developed that could deliver nuclear warheads deep inside enemy territory, the days of the manned bomber seemed to be numbered. However, the USA, Russia and many other nations have continued to develop their strategic bomber fleets.

Manned bombers have many advantages over guided missiles. Once launched, they can be recalled. They can be armed with a much greater variety of weapons and used in counter-insurgency operations or conventional limited warfare – in addition to all-out nuclear war. Missiles

Small 'strike' aircraft carry bombs for use against ground troops and military targets. They can be just as effective as the huge bombers that reduce cities to rubble.

are effective deterrents, but they are really only weapons of last resort and so only have limited uses.

Heavy bombers are strategic weapons whose targets are often cities and towns far removed from front-line fighting. Warring nations have long since abandoned the fiction that enemy civilian casualties are the unfortunate by-product of attacks on war factories in built-up areas. The

medium and long-range bomber is, by threat or direct action, intended to crush a nation's will to resist by inflicting massive damage to major cities and huge civilian casualties.

Heavy bombers

The Russian air force is equipped with a wide range of bombers. Most remarkable of all these, perhaps, is the seemingly old-fashioned propeller driven Tupolev TU-95/142 'Bear'. Although it first flew in 1954 it remains in production to this day. It is the heaviest of the serving Russian bombers and has the immense radius of action of 8285 kms. It is also used for long range reconnaissance duties and was regularly intercepted and shadowed by NATO Phantoms and Tornados fighter aircraft over the North Sea.

Other serving Russian bombers are the TU-16 'Badger' and TU-22 'Blinker'. Both are jet aircraft and the

The Fairchild A10 Thunderbolt is a 'close-support' aircraft, destroying enemy positions without damaging nearby friendly forces.



Blinder was the Russians' first super-sonic heavy bomber.

One of the most impressive of heavy bombers, however, is the TU-22M 'Backfire' which is capable of flying at speeds of up to Mach 2 – that is, twice the speed of sound. But the latest Russian heavy bomber is the Tupolev 'Blackjack',

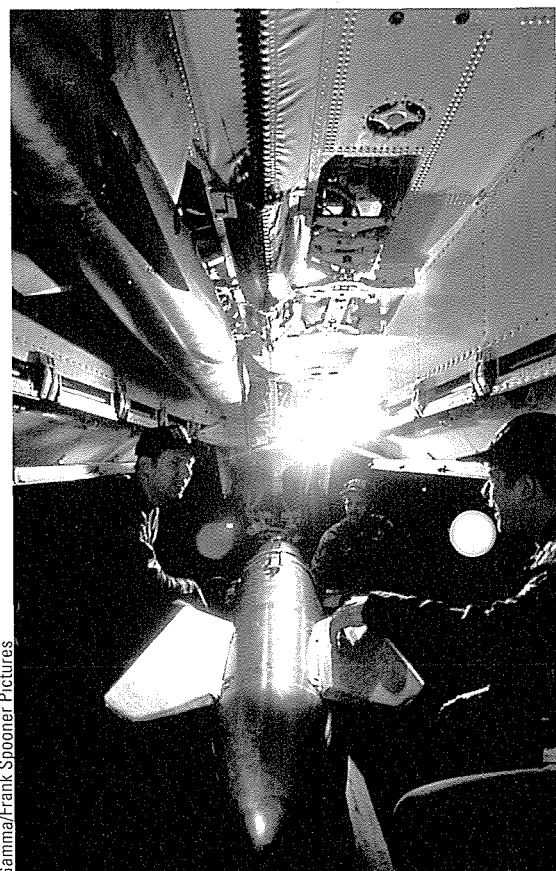
though. They are large aircraft that must operate over enemy territory, making them a target that is easy to detect and difficult to protect. Radar systems can 'see' bombers approaching and direct interceptor aircraft and anti-aircraft fire towards them. And the development of effective surface to air missiles have made

many aeroplanes are lost in training accidents.

Another way around the problem of flying into enemy air space is to equip bombers with a 'stand off' capability, that is the ability to launch a cruise missile at a target from outside the enemy's main defences. Air-launched cruise missiles are now

The 'Bear', the huge Tupolev TU-95, can fly at up to 925 km/h – faster than was once thought possible for a propeller-driven plane.

Purpose-built strategic bombers have huge bomb bays. Smaller 'attack' aircraft have their weapons slung below the airframe.



Gamma/Frank Spooner Pictures

DOD/TRH Pictures

which has recently come into service with the Russian air force. This combines a Mach 2 dash performance with the range to fly a two-way mission against targets of America from Russian bases inside the Arctic circle.

The United States Air Force has been equipped with the Boeing B-52 bomber since 1955 but it has been continually updated. It is now capable of low-level penetration and armed with air-launched cruise missiles. It remains the world's longest range bomber.

Variable geometry

The latest US bomber to go into service is the Rockwell B-1B. This is a variable-geometry aircraft with a maximum top speed of Mach 1.25. Some one hundred of these aircraft have been ordered by the United States Air Force and should be in service soon.

Bombers do have their problems

high-altitude bombing out of the question.

To counter this, new bombers are designed to fly low and fast – below the enemy's radar coverage. This meant equipping the aircraft with terrain-following radar – so that the plane can follow the contours of the ground below – and cockpit information systems with 'head-up' displays so pilots are able to read their instruments and look out of the cockpit window at the same time. This is very necessary when flying just 30m above the ground at speeds that leave no margin for error.

Low flying

Flying at very low levels also puts enormous stresses and strains on the airframe, so the new generation of low-level bombers has to be built particularly strongly. Low-level flying requires enormous skill. The training is lengthy and extremely expensive. A large number of pilots are killed and

The neutron bomb is a much more effective tactical weapon than a conventional nuclear bomb. Its greater radiation kills many more troops, even though its blast is considerably smaller.

10 Kilotonne Nuclear Bomb

tank knocked out, crew might survive

2000 metres

distance from ground zero

1000 metres

500 metres

250 metres



BOMBS AWAY!

minimized, making it difficult to spot using infra-red detectors. As a result, the B-2 is an incredibly expensive aircraft and only a very few have been produced for use in special circumstances.

Cruise missiles

While free-falling bombs are still used by modern air forces for close support of ground troops, the superpowers rely to a great extent on air-launched cruise missiles so that the aircraft do not have to overfly heavily defended targets. Principal US weapons are the AGM-69A SRAM and the AGM-86B ALCM

British Aerospace



Alan Emoult & Emoult Features/IDI

approaching the same accuracy as bombs delivered closer to the target but may still go astray.

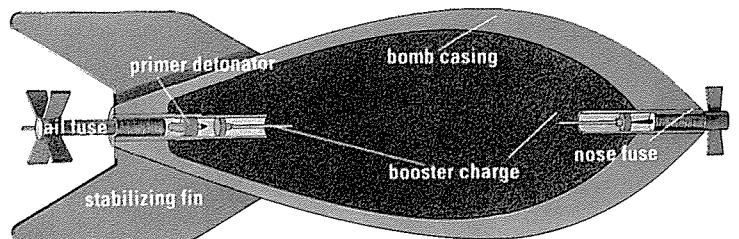
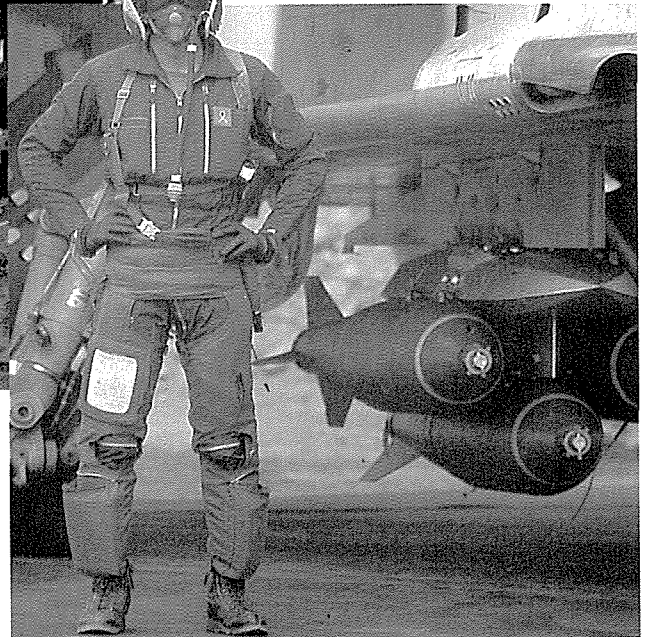
The ideal solution is to design an aircraft that can fly wherever it wishes and still not be seen by radar. This is the thinking behind the Northrop B-2 'Stealth' bomber, which was unveiled in late 1988. By rounding off all corners and using non-metallic materials, there is little for radar waves to bounce off.

Invisible

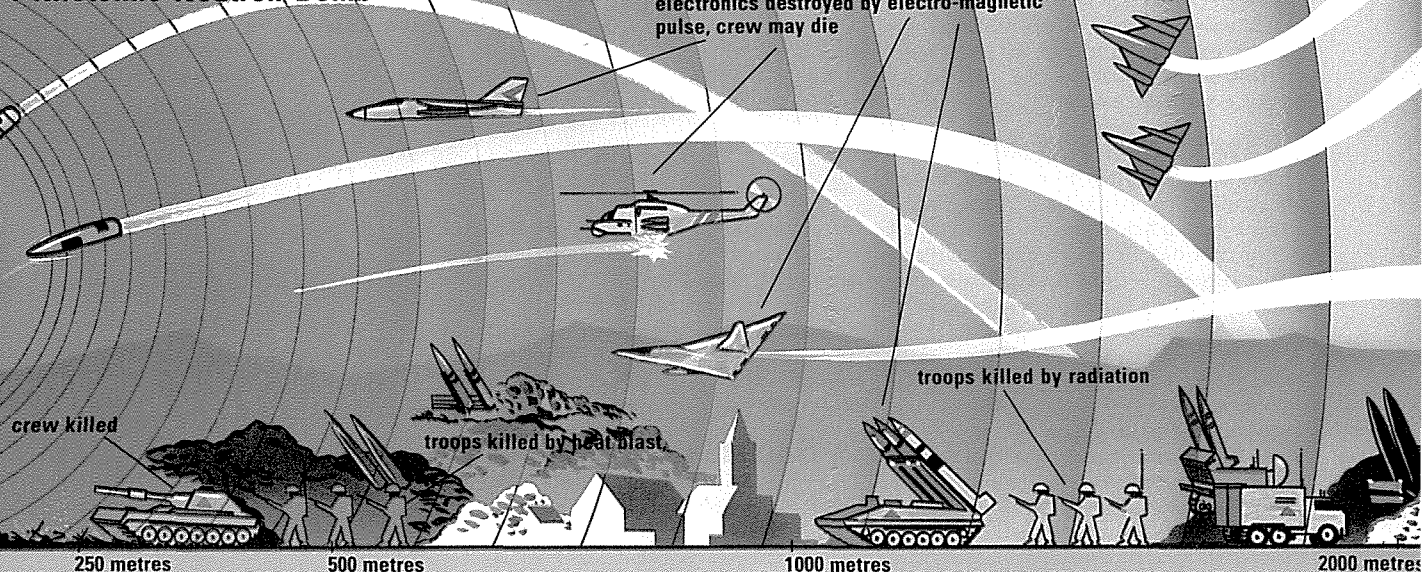
The B-2 is also designed to be very quiet so it is hard to hear and to give off a minimum of exhaust smoke and vapour trail so it is hard to see. The amount of heat it gives off is also

A small 'attack' aircraft, such as the Jaguar, carries a huge array of weapons. During their training to fly low and fast many pilots (inset) are killed.

A general purpose bomb is designed to explode in the top floors of buildings. The firing pin is screwed into the booster charge by the propellers as the bomb falls.



1 Kilotonne Neutron Bomb



THE ANTI-AIRFIELD MINE - A HIDDEN THREAT



Hunting Engineering Ltd

The HB876 is an 'area denial mine' that is designed to disable airfields. Some 430 of these tiny mines are dropped in a canister with 60 'cratering' bombs - explosive devices designed to cause huge craters in runways. The canister opens as it falls from the plane, cratering the runway and the rest of the airfield. The mines are scattered around the edge of the craters, going off when approached or automatically at random intervals. Each mine contains two warheads, one to destroy bulldozers or armoured clearance vehicles and one fragmentation charge to kill anyone nearby. The combination of craters and mines keeps the airfield out of service for a very long time.

which has a range of up to 2500 km. The Russians use AS-3 'Kangaroos', AS-4 'Kitchens' and AS-6 'Kingfishers'. The longest reach that can be achieved by the systems is 650 kms, but the latest Russian ALCM, the AS-X-15, will give the 'Bear', the

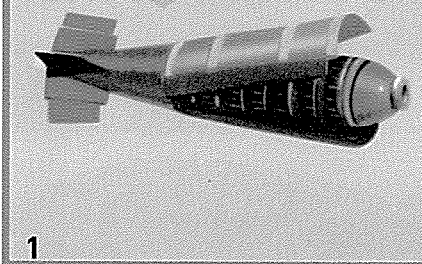
the Jaguar to provide part of their tactical nuclear strike capability, even though this aircraft is not truly all-weather. The Jaguar has an Inertial Navigation System that is allied to a pilot's moving map display, but it can end up more than 1.6 kms off target.

Terrain avoidance

No such limitations affect the Panavia Tornado, which is equipped with an automatic terrain following radar suitable for flying at 30m over enemy territory, day or night. This is an improvement on the terrain-avoidance radar fitted to aircraft such as the American F-111 which provides only a warning of obstacles ahead as a result of which pilots have to take rapid evasive action.

As well as navigation aids, strike aircraft

Once a cluster bomb (1) has dropped clear of the aircraft, the outer skin strips away (2). An inflating bag ejects them and tiny parachutes slow each bomblet (3).



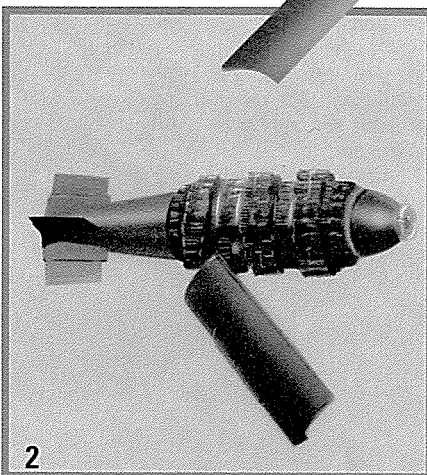
'Backfire' and the 'Blackjack' bombers a stand-off range of some 3000 kms.

One of the most common purposes to which military aircraft are assigned is the assault upon the enemy's ground forces and ground installations. Most of the world's air forces possess aircraft of this type, which are normally classified as 'strike' or 'attack' aircraft.

Strike and attack

Attack is usually taken to mean a sortie against forces close to the front line or in the immediate rear area of the battlefield. Strike missions on the other hand are aimed at targets further away and can involve the use of nuclear weapons.

In this respect the strike aeroplane has some overlap with the duties of the heavy bomber. Typical targets for tactical strike/attack aircraft would be airfields and supply lines, with the aim of starving the front line of all forms of support and forcing troops to retreat without fighting. The United Kingdom and France rely on



are equipped with a package of penetration aids, including electronic jamming equipment to confuse enemy radars, chaff and flare dispensers to decoy surface-to-air missiles and self-defence air-to-air missiles to take on and destroy any enemy interceptor aircraft.

Backseaters

The more advanced strike aircraft have two crew members, one of whom is the backseat weapon systems operator - or backseater -

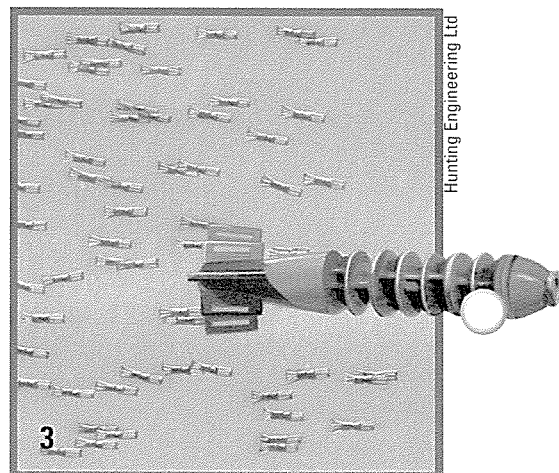


responsible for operating all the aircraft's electronic systems. The weapon carrying capability of attack/strike aircraft ranges between the Sukhoi Su-7 Fitter's 2500 kg and the Fairchild A-10A's amazing warload of 7258 kg. Armament options normally include a cannon of 20 mm or 30 mm calibre and the full range of bombs, rocket pods, cluster bombs and occasionally air to surface - or SAM - missiles.

Cluster bombs

Cluster bombs are essentially a container filled with hundreds of 'bomblets'. These might be designed to penetrate the top armour of a squadron of tanks or be scattered the length and breadth of an enemy airfield runway, giving the enemy the problem of disposing of hundreds of bomblets before they can use the runway again. They are also vicious anti-personnel weapons that can kill, maim and injure large numbers of people in one go.

Despite the thaw in the Cold War, weapons like these - along with conventional incendiary and high-explosive bombs - will still be used in the hundreds of small-scale wars that are waged around the world.

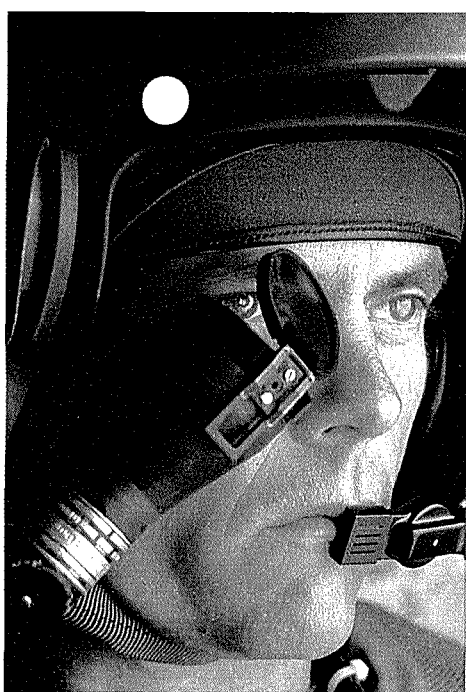
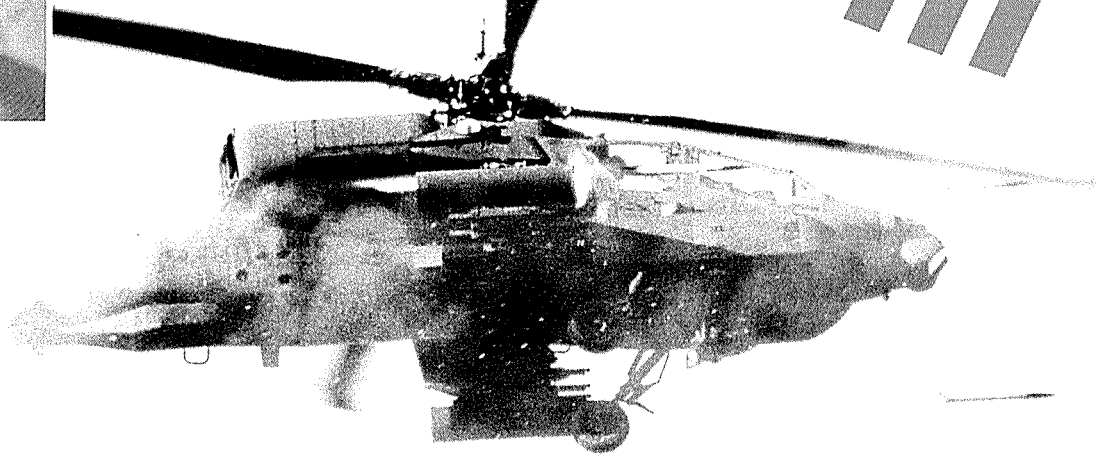


ATTACK HELICOPTERS

ANTI-TANK MISSILES

AUTOMATIC TARGETING

GUNSHIPS



© Frederick Sutter 1990

Attack helicopters such as the Apache AH-64 are formidable weapons systems, capable of destroying main battle tanks over 1 kilometre away. The Integrated Helmet and Display Sighting System (above) allows crew members to aim at targets just by looking at them.

ARMED TO THE TEETH WITH anti-tank missiles, line-of-sight rockets and rapid-firing heavy machine guns, skimming trees at 320 km/h and capable of turning in its own length, the modern attack helicopter not only reaches the targets that other aircraft cannot – it destroys them.

Helicopters were first used on the battlefield for carrying troops from one location to another, for casualty evacuation and for scouting and observation. When the enemy started

shooting at them, light armament was fitted for defensive purposes. It was soon realized that the helicopter was the ideal firing platform for wire-guided anti-tank missiles. These first 'attack helicopters' or 'gunships' were essentially utility machines with 'strap on' offensive missile systems.



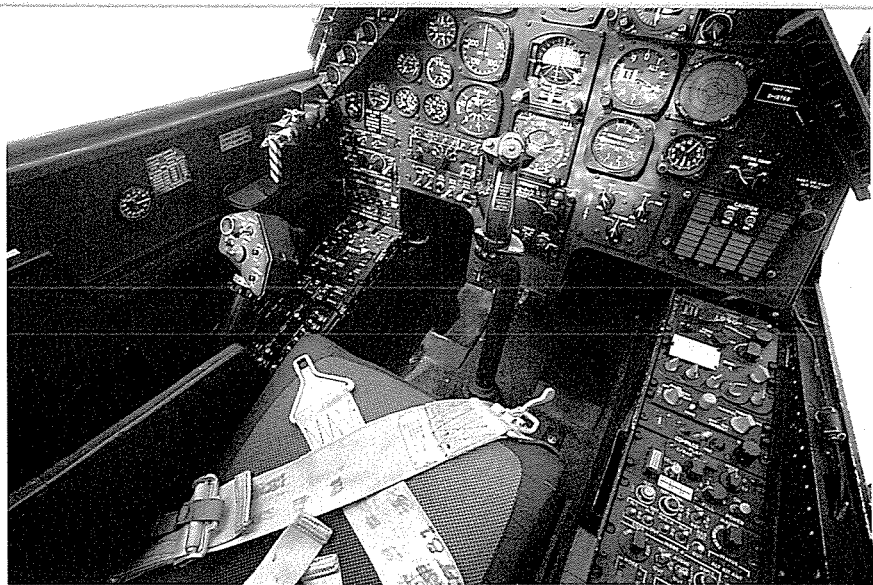
Huey Cobra

The first real attack helicopter was the AH-1 Huey-Cobra. Although this aircraft first entered service with the US Army in 1969, it is still in use, with US forces and other armies.

The Cobra is a slim, sleek and fast attack helicopter. The pilot and weapons operator sit one behind the other. The resulting narrow profile of only 91cm allied to low cabin height makes the AH-1 more difficult to hit with small-arms fire and easier to camouflage on the ground. It carries a combination of 'mini guns' firing thousands of rounds per minute and 40mm grenade launchers in the nose turret with rockets and gun pods on the four pylons attached to the stub-wings. The turrets are 'slaved' to the cockpit weapon sights.

Alain Ernout & Ernout Features/ID1

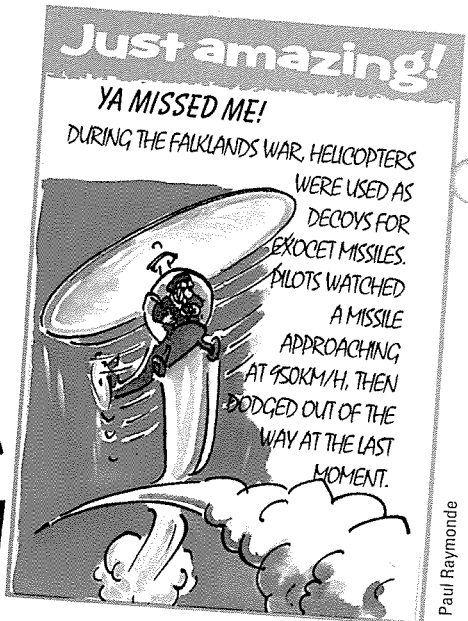
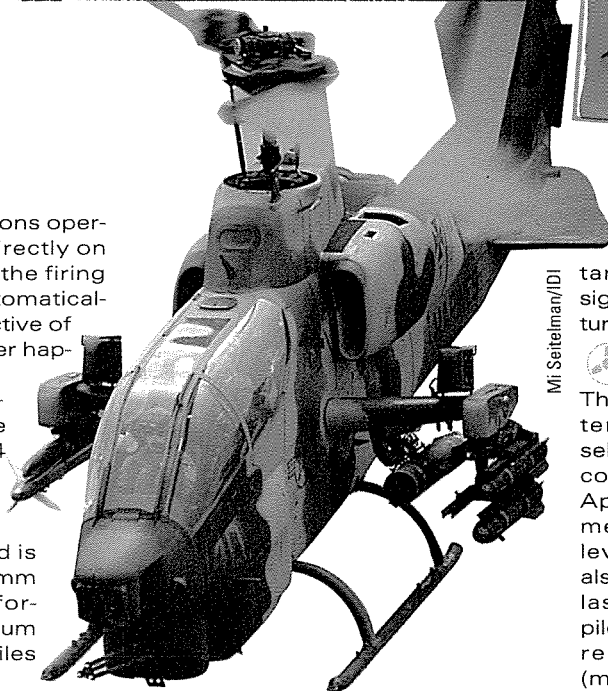




The pilot's view of the Bell AH-1 Cobra (right). The crew compartments are armour-plated, capable of protecting the pilot and gunner from hits by 12.7mm armour-piercing rounds.

This means that if the weapons operator looks at a target not directly on the flight path and presses the firing button the miniguns will automatically train on the target irrespective of which direction the helicopter happens to be flying in.

The present attack helicopters are even more impressive. The US AH-64 Apache is larger, heavier and much more powerful than the Cobra. It has a top speed of 296 km/h and is armed with a chain gun 30mm cannon carried under the forward fuselage with a maximum of 16 Hellfire anti-tank missiles



on the four weapon stations on the stub wings.

The Apache's avionics include target acquisition and designation sights (TADS) carried in a rotating ball turret on the nose of the aircraft.

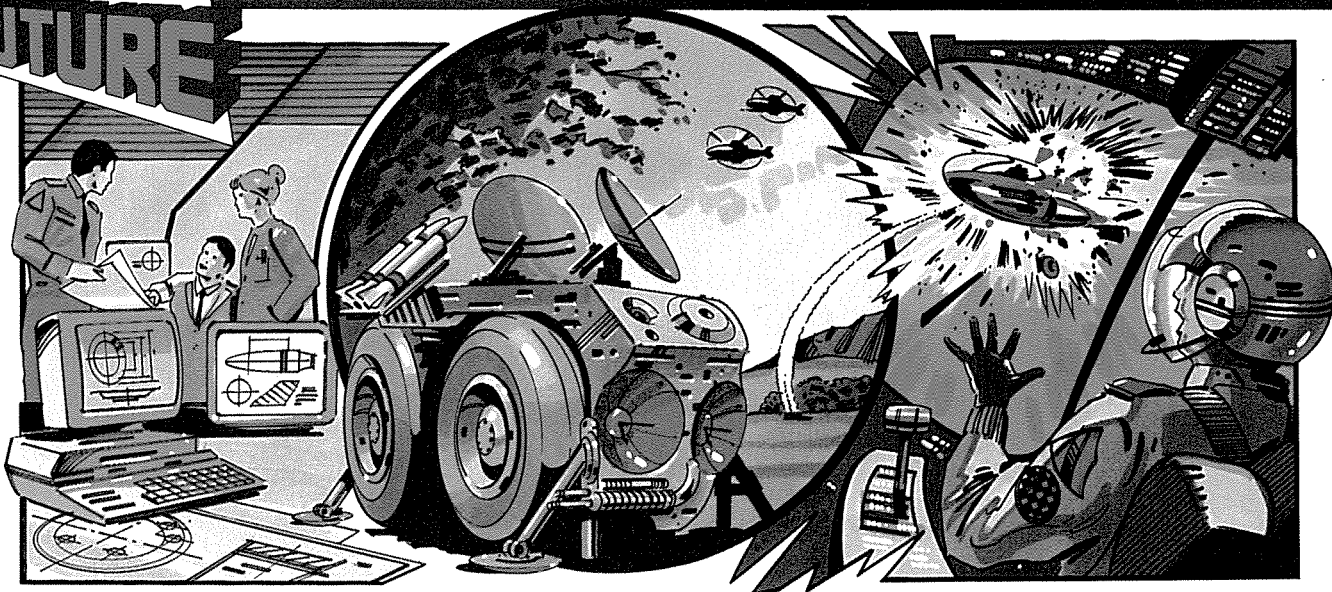


Sighting targets

This is a computerized targeting system, allowing enemy forces to be selected and 'sighted' while the helicopter is concealed. In addition, the Apache has thermal imaging equipment to allow the pilot to fly at low level at night or in bad visibility. It is also equipped with passive radar and laser warning receivers so that the pilot knows if he is under attack, infrared and radar jammers and chaff (metal foil radar decoy) dispensers.

INTO THE FUTURE

THE DEADLY EARS



▲ The latest battlefield weapons system under development is the intelligent 'helicopter mine', designed to secure an area against enemy air movement.

▲ The weapon will 'listen' for helicopters with an array of microphones, identifying an enemy aircraft by the unique frequency 'signature' of its main and tail rotors.

▲ An onboard computer will determine the position and flight path of its target, then unleash a homing ground-to-air missile, destroying the helicopter.

 STORY BOARDS

 PHONEMES

 LINE TESTS

DRAWING POWER

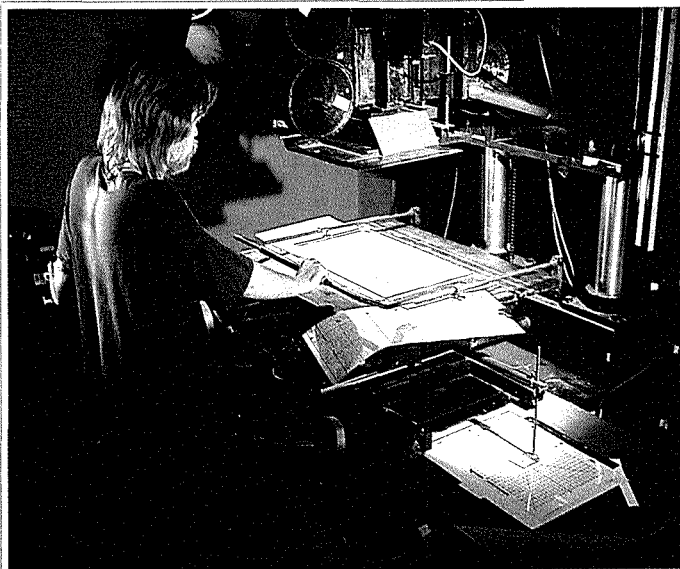


Kohal Collection
ANIMATION IS THE ART OF the impossible. Anything can happen – elephants fly, rabbits talk, and magic is normal. But the most impossible thing of all is that nothing in animation ever actually moves.

Animation is possible because the brain interprets a series of still pictures flashed on a screen at a rate of 24 frames a second as a single image. If each image is slightly different from the one before, the illusion of movement is made.

But certain conditions have to be

Who Killed Roger Rabbit? *used computer technology to marry cartoons and live action. But the animation was shot the old fashioned way, frame by frame on a rostrum camera (inset).*



met. The jump between pictures must not be too big and the time between each jump must not be too long. Getting these things right is the art of animation.

Animated films are shot frame-by-frame. This means that the image – a picture or an object – is shot then moved or changed in some way and shot again.



Line drawings of the major elements of the shot are assembled to check that everything is in the right position. The coloured foreground image (right) is produced on clear plastic so that the background does not have to be redrawn.

In the first or pre-production stage, the director works closely with a scriptwriter and designer. The scriptwriter has to create a story that is visually suitable for animation, while the designer has to create characters that can easily be animated. They must not have too much detail as each detail has to be redrawn thousands of times.

The characters are first worked out as personalities. The way they move and talk, the way they dress and the things they do are drawn out on a model sheet which is the guide for the animators.

The next stage is to draw up a

story board. This is like a comic strip version of the script. It shows the action, dialogue and camera shots. This is acted out to give the timing of each scene. When the timing is right, the voice track is recorded.



The animatic

The storyboard is then shot on a single-frame video recorder and the sound track added. The resulting tape is called an animatic. Although it only contains still pictures, the animatic gives a very good idea of how the final film will look. But changes can still be made quickly and cheaply.

The animatic not only shows what the film will look like, it shows what backgrounds, sound effects and spe-



The 'rushes' – raw footage straight from the camera – are viewed in the cutting room. When the film has been edited, the pictures and sound have to be synchronized (below). The bar sheet gives a detailed breakdown of every single element of sound.

cial effects might be needed. All of this has to be worked out very accurately before the film goes into production.

When the voice track has been finalized, the editor does a breakdown of the speech, splitting words up into 'phonemes' or individual sounds. The word 'hello' has two phonemes 'ha' and 'lo'. They have different lip shapes.



Bar sheets

The editor records where the sounds start and end on 'bar sheets', which are timed in frames. A frame is 1/24th of a second and the word 'hello' lasts 20 frames. The animators need to know exactly where the phonemes start and end so that they can draw in the right mouth shapes.

If the animation has to be timed to the sound effects – footsteps, door knocks, the thunder of hooves – or music, these sounds have to be recorded before the animation starts. But other sounds – a single crash, background music – can be added afterwards to fit the animation.



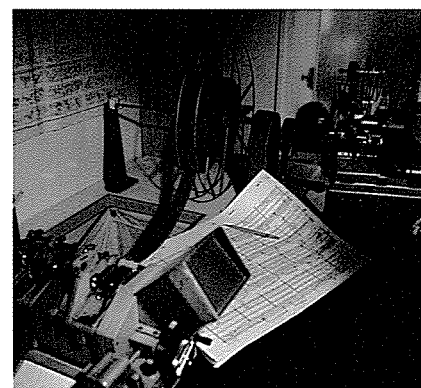
The layouts

While the editor is doing the sound track breakdown, a layout artist uses the storyboard as a guide to do the layouts. These are large sketches of scenes showing the background and the character positions within each

MAKING THEM MOVE

There are three major techniques of animation which are used in cartoon films and combined with live action to produce special effects in horror, adventure and science fiction films:

- Drawn animation covers those methods that use a series of drawings, with one replacing the next. These images are usually drawn on paper or clear plastic, but could also be painted on a canvas, chalked on a blackboard or drawn on a computer screen. Drawn animation is the most expensive method, but offers the most control. Mickey Mouse is drawn animation
- Cut-out animation uses flat cut-out shapes normally made of cardboard. The shapes can be hinged to create the movement as with the arms and legs, or the shapes replaced by other shapes that are slightly different. This method is quick and cheap, but very limited.
- Model animation uses 3D figures and objects. These can be puppet figures or modelled from plasticine.



scene. The layouts help the animator to plan the movements.

When the animators start work, they will sketch out the animation as pencil line roughs. These are then shot as a 'line-test' to check the timing and the movement of the animation. Many commercial studios use sophisticated computerized line-test machines. These systems save a great deal of time as they allow the tests to be shot and replayed immediately. They also let the animator change the speed of a movement, add and subtract frames, move scenes around and store the results –

Just amazing!

ARTISTS' NIGHTMARE

TO PRODUCE A FULL-LENGTH 90-MINUTE CARTOON FEATURE FILM, FROM STORY BOARD TO THE FINAL MOVIE, CAN TAKE OVER 1 MILLION DRAWINGS – THAT IS OVER 11,000 A MINUTE.



Paul Raymond



all without having to cut film or reshoot a single frame.

While the animators are working on the action, other artists are working on the backgrounds, titles and effects like rain and snow. These are specialized areas of artwork often done by painters and illustrators. Large animation studios employ a range of artists with different skills.

When the animation has been line-tested and corrected, the pencil drawings are then traced on to a clear plastic sheet called a cel and painted. They are numbered in sequence and listed on a 'dope sheet' ready for the cameraman to shoot.

The purpose of using a cel is that a drawing can then be made up in parts. The head, body, arms, legs and face

can all be drawn on separate cels and overlaid, then only the action part of the drawing needs to be redrawn to create movement. For example, a man only needs to have the sequence of legs redrawn to make him walk.



Shooting single frames

When each scene is complete, it is checked to make sure all the drawings are in the correct sequence with their proper backgrounds. They are then sent to the cameraman. The drawings are photographed on a specialized animation camera that is designed to shoot single-frames.

These 'rostrum' cameras have a column that the camera can move up and down on to produce a zooming effect as the camera moves in and out of the scene. Panning effects – moving across the scene or up and down – are done by moving the table the cels sit on under the camera.



'Mixes' and 'fades'

The computer can also control the camera lens so that 'mixes' – from one scene to another – and 'fades' to black can be programmed as well.

In the film *Who Framed Roger Rabbit?* the problem was to make the animation seem to be part of the live-action scene. To do this meant

Television cartoons are usually made on film, then transferred on to videotape in a colour correction suite.

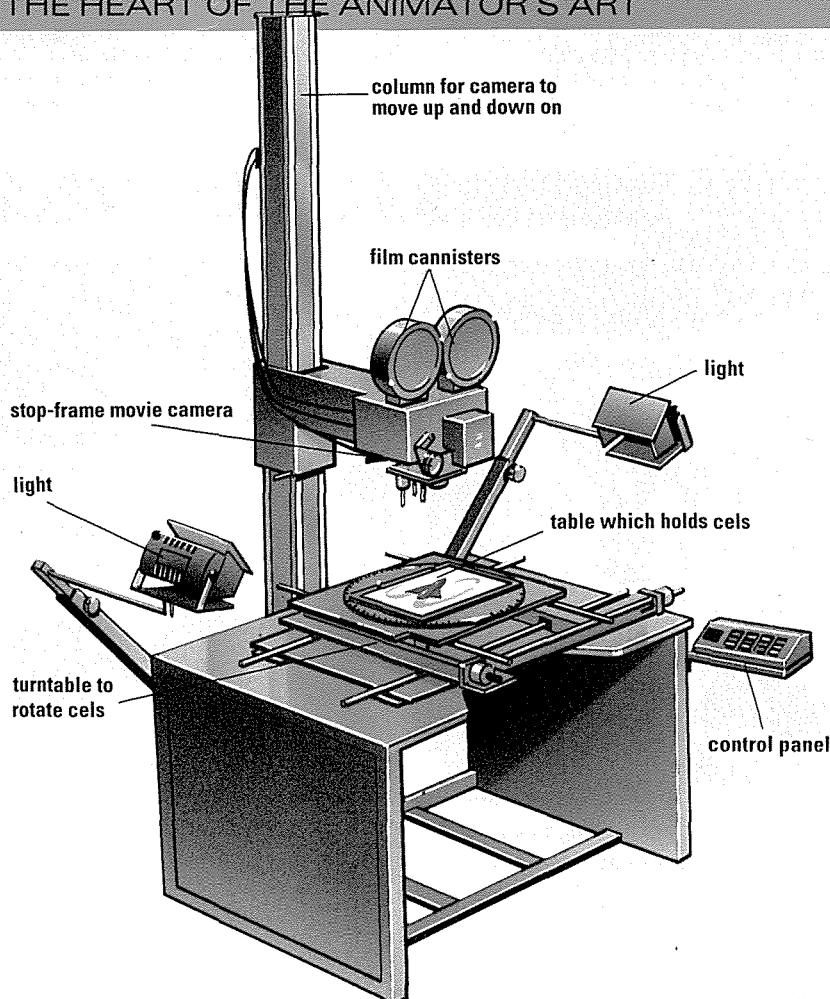


THE ROSTRUM CAMERA – THE HEART OF THE ANIMATOR'S ART

The rostrum camera shoots the drawings that make up a cartoon film, frame by frame. The clear plastic cels – each carry elements of the background, foreground and characters – are laid on the camera's table, layer by layer, held in position by pegs.

Elements of the character cel can be changed and the background cel moved, shot by shot, to create the impression of movement. But to make a cartoon film even more life-like – or more like a conventional movie at least – the camera needs to zoom in and out of the action and pan across it. To create a zooming effect, the camera is moved up and down on the column. And to create panning, the cels on the table are moved from side to side or rotated under the camera.

One of the problems with rostrum cameras is vibration from traffic. Many are installed in the basements of buildings to minimize this effect.



shading the cartoons to give a 3D image and light and shadows that were consistent with the live-action people. A technique called computerized 'ray-tracing' was used. The computer selected the sources of light in a scene and worked out how the patterns of light and shadow would fall on a solid in its path.

When the film has been shot, it is sent to the laboratories for processing. The laboratories keep the processed negative and send a print back to the studio for editing. This is called a cutting copy because the editor uses it for cutting when matching the film to the voice track.

When the cutting is complete, the



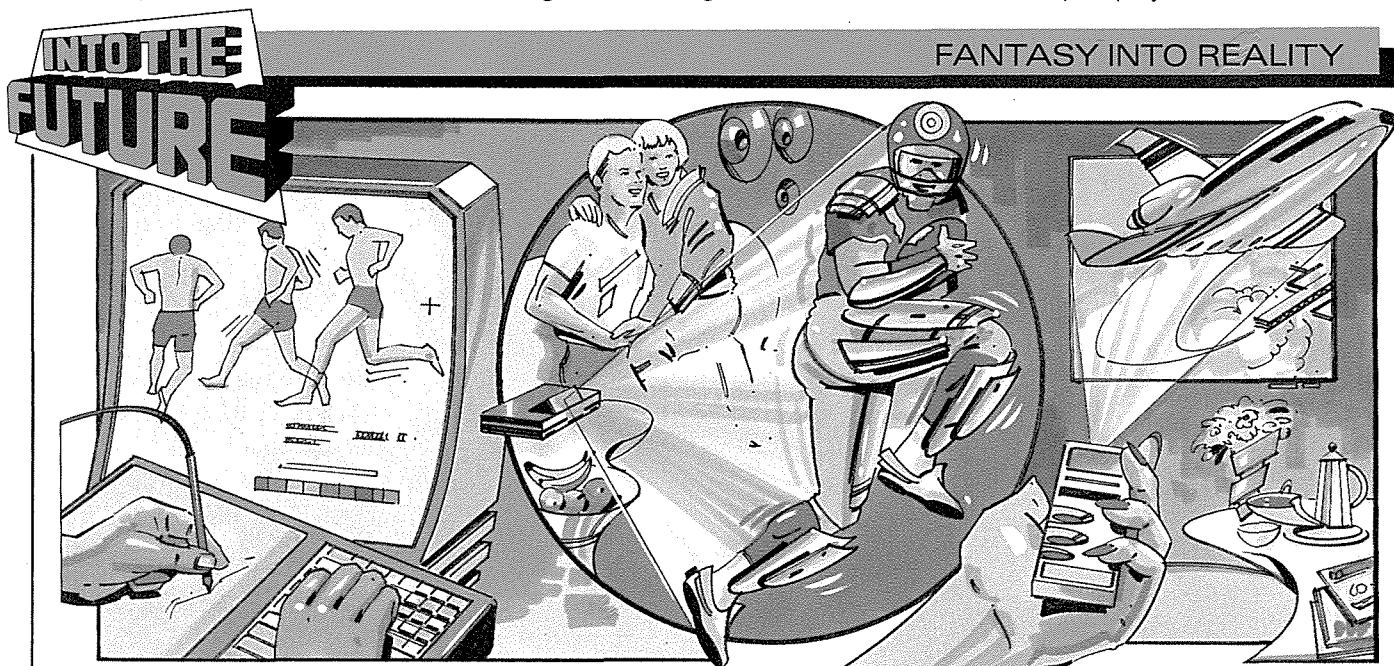
Hasbro & Sunbow Productions Inc/Ronald Grant Archive

All the elements work together to make an exciting film with lots of 'action' produced by thousands of still pictures.

The completed soundtrack and the edited picture are sent back to the laboratories, where the original negative is cut to match the edited version. The soundtrack is transferred from magnetic tape to the optical track of the film. The sound and image are then combined on a single piece of film ready for projection.

In special effects animation a special camera is used that shoots both on film and on video tape. This makes it easier to blend in cartoon sequences.

picture and the three separate voice, music and effects soundtracks are run together in a dubbing theatre. The sounds are adjusted to fit the action in the pictures, then dubbed or mixed together on a single track.



▲ Already a computer 'paintbox' can be used to manipulate images. It should soon be possible to build up enough images of an actor to animate a 'real' figure at will.

▲ 3-D TV already allows an image to move around in a confined space. So an animated actor or a cartoon figure could be made to walk around your living room.

▲ As paintbox technology becomes more widely available, it may be possible for you to control your own interactive animated films at home.

Joe Lawrence



ROVING EYE CAMERA



MICROWAVE LINK



ACTION REPLAYS

OUTSIDE BROADCAST

A CUP FINAL, A ROYAL wedding, news in the making – all are major events covered live on television by outside broadcasts.

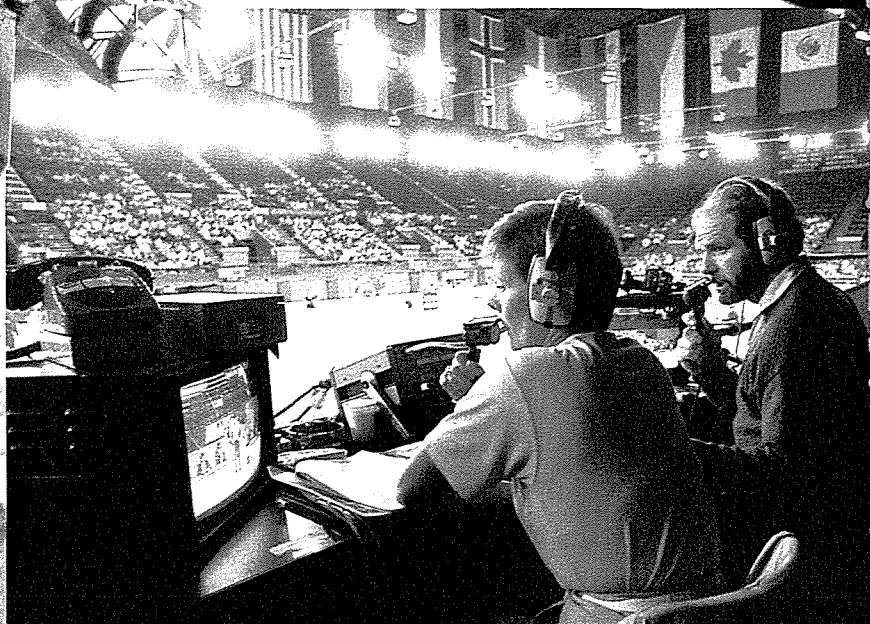
At the heart of a sports outside broadcast is the scanner, or MCR (mobile control room) – a vehicle as large as a luxury coach that houses the production team and its equipment. In the scanner's control room, in front of a bank of monitors, sit the director, production assistant, vision mixer and technical supervisor. These monitors show pictures of the event coming in from various cameras set up in strategic positions.



Picture quality

A second compartment inside the scanner houses the sound engineer with an assistant. Finally, in a third section are the engineers in charge of picture quality and the operators responsible for action replays.

Communications satellites, located about 35,000 km above the equator, relay major sporting events from outside broadcast units (below) across continents.



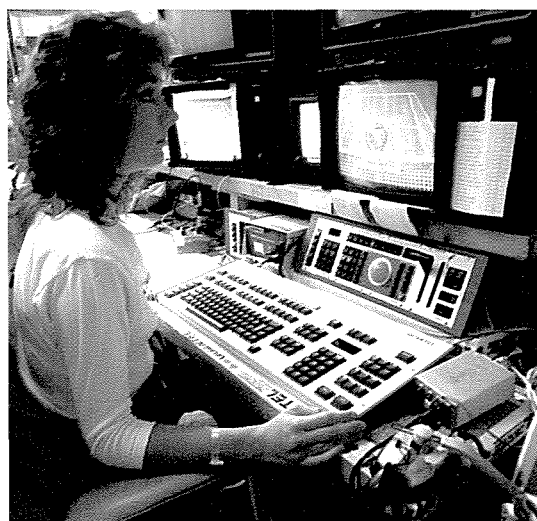


Television coverage of a typical horse-racing meeting involves mobile control room vehicles, a roving eye camera car and an aerial (on the scaffold tower) to send signals back to base.

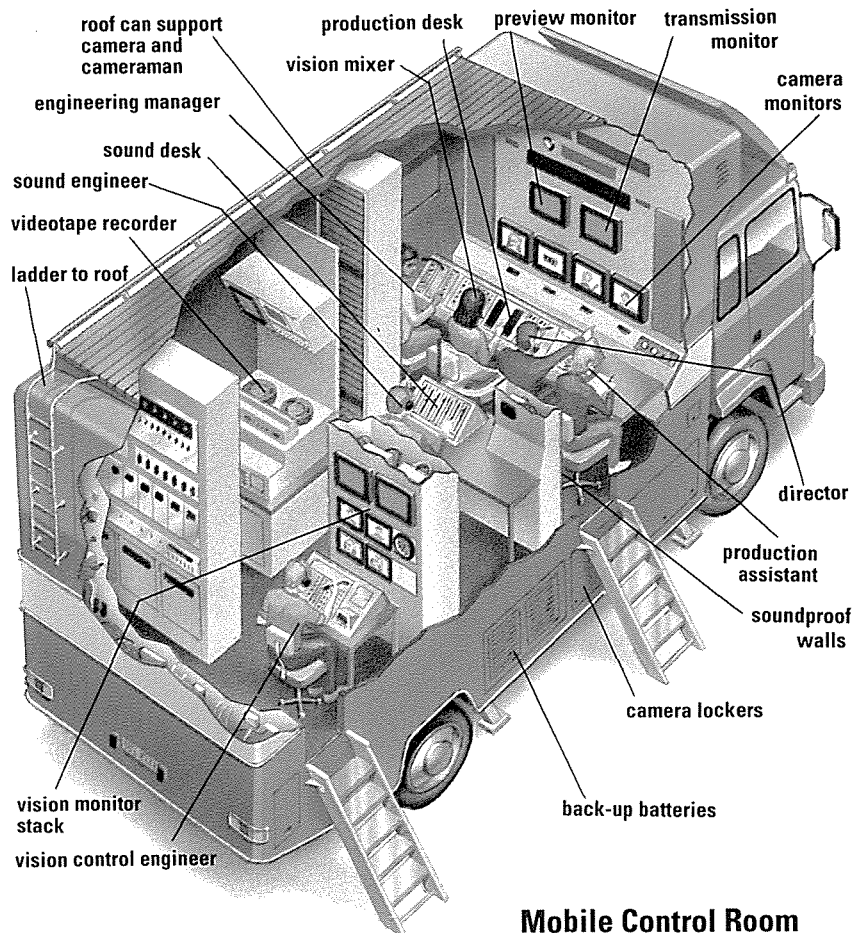
A vision mixer combines computer-generated titles with the selected camera image. The large van (below right), called a scanner, is the heart of the outside broadcast operation.

broadcast and must be carefully planned by the director well before the event. Cameras may be set up at ground level, on top of vehicles, buildings, or scaffolding platforms, and even on board helicopters or airships to obtain the best view. To cover a football match, for instance, a mixture of cameras will be

used. Some will be high up and fitted with wide-angle lenses to take in all the action, while others at pitch-level will be equipped for close-ups. Still other cameras may be stationed for action replays from different angles and in the commentary box for interviews after the match. A roving eye camera is some-



Mobile Image The director and production team are in constant communication with the external camera and sound crew via two-way headsets. Signals from the television cameras and microphones travel along cables into the rear of the scanner. After being chosen and processed, the pictures and sound to be broadcast are sent either by radio link or cables to the central television station for transmission into homes around the country. The positioning of cameras is vital to the success of an outside



Mobile Control Room

times used for events like horse racing. The camera is mounted on top of a van that drives alongside the horses at the start of the race, then moves on to follow the leaders around the course. A radio link van relays picture signals from the roving eye vehicle to the scanner parked near the grandstand.

For outdoor events like cricket and football matches it may be impossible to place a microphone near to the source of sound. For this reason, highly directional gun mi-

crophones are often used. They will pick up sounds clearly from over 50 metres away provided they are pointed directly at the source. Gun microphones are usually mounted on top of television cameras to pick up the sound of the action being broadcast.

Commentators at an outside broadcast usually sit in a box overlooking the whole scene, but they also have small monitors showing the view from each camera. This allows

At the television station, the signals received from the outside broadcast are boosted and then retransmitted. This may be done using radio waves beamed from a tall aerial, by underground cable, or by satellite.

The majority of homes receive the television signal by radio waves. The separate picture and sound signals travel on carrier waves – one wave for each signal. They radiate out from a transmitter aerial, like ripples on a pond, at 300,000 km per second. But

ACTION REPLAYS

Exciting moments in sport can be quickly shown again using action replay equipment. This consists of two special video discs. Each side of a disc holds up to 9 seconds of picture time on 450 separate tracks. Magnetic heads record all the time an event is happening, wiping out the previous recording each revolution. To show an action replay of, say, a goal being scored, an operator resets the head to the start of the action. For slow motion, each track, containing a tiny fragment of the action, is replayed more than once – twice for half speed, four times for quarter speed.

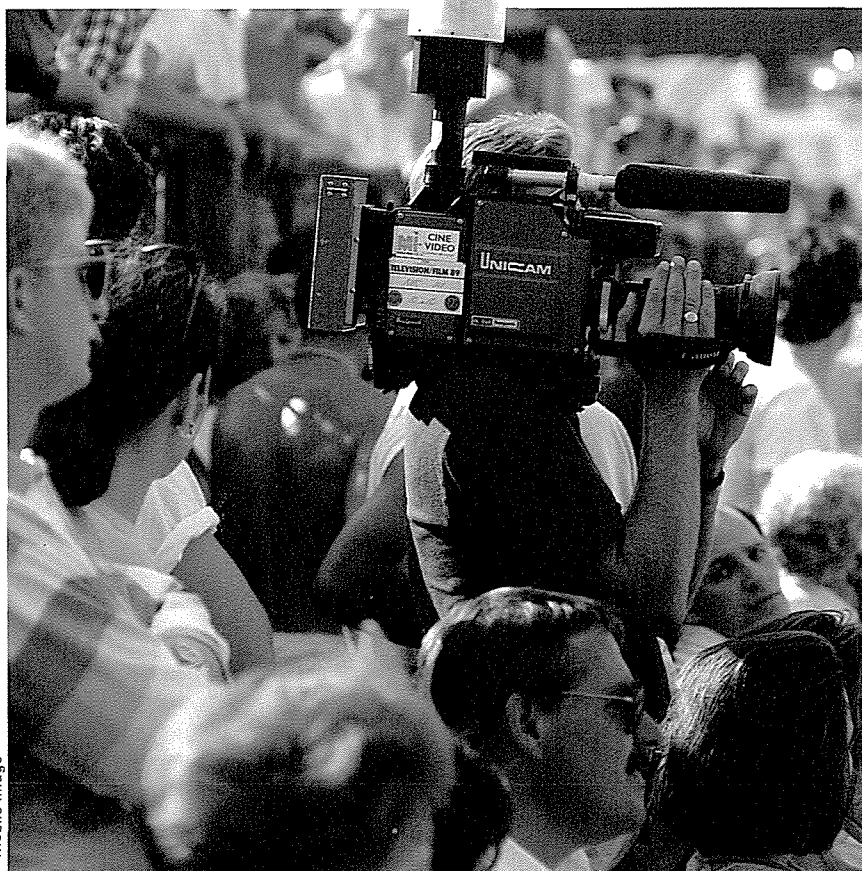
the waves become weaker as they travel further from the transmitter.



Transmitter network

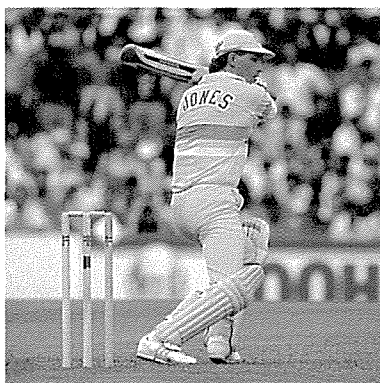
Because radio waves travel roughly in straight lines, tall buildings or hills interfere with the signal. So, to cover a whole country, a network of transmitters is necessary. In densely populated countries, there are transmitters about every 60 km.

To beam the signals of a live outside broadcast, such as the Olympic Games, to countries all over the world, however, a satellite must be used. This acts like a giant 'tower in the sky', transmitting carrier waves over vast distances.



Mobile Image

IN THE FIRING LINE



Channel 9 Network

A portable video camera, with a built-in microphone is hand held in the midst of a Wimbledon tennis crowd, providing a fan's eye view of the match on court.

them to report on what they can see directly as well as what the audience can see on their television sets.



Microwave link

From the scanner, the selected television pictures and sound are sent to the television station. If cables, or land lines, are available, the signals are sent this way. Otherwise, the outside broadcast is beamed by microwaves from dish-shaped antennae set up near or on the roof of the scanner vehicle itself.

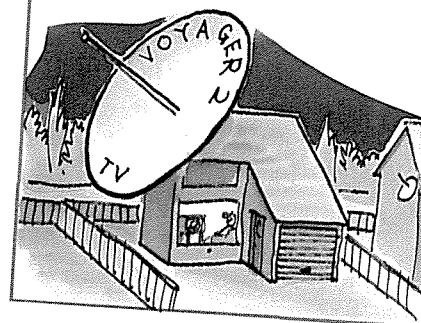
Microwaves, which are short-wavelength radio waves, do not interfere with the longer wavelength radio signals used for transmissions into people's homes. However, because microwaves cannot penetrate hills or other solid objects, a series of aerials may be needed to relay them over a long distance to the station.

Miniature sound and vision equipment is now used at cricket games. The centre stump is hollowed out and a tiny television camera placed inside to give a batsman's eye view of the pitch, while a microphone, inserted into the base of the stump in the same way, picks up the sound of ball on bat.

Just amazing!

OUT OF SIGHT

THE MOST REMOTE OUTSIDE BROADCAST TOOK PLACE ON 25 AUGUST 1989 WHEN VOYAGER 2 SENT BACK PICTURES OF NEPTUNE FROM A DISTANCE OF 5 BILLION KM.

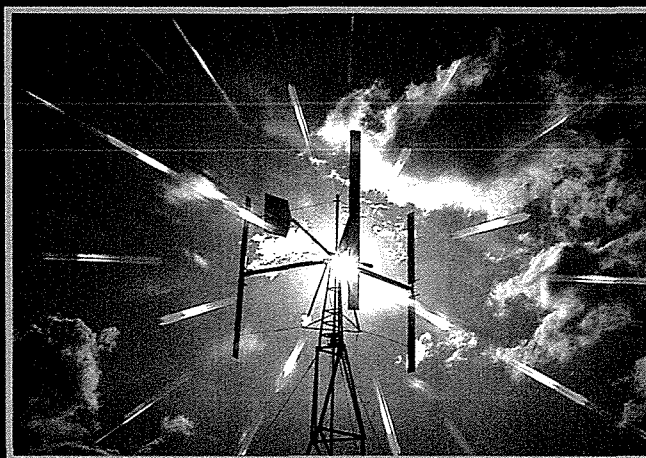


Paul Raymond



Diffraction filters are scribed with minute and closely spaced radial lines. These produce spears of colours from highlights that can be rotated for best effect.

Coloured filters can produce bizarre results. Here orange and blue filters have been used to radically transform an early evening photograph of a field of wheat.



Martin Bond/Science Photo Library



Jonathan Watts/Science Photo Library

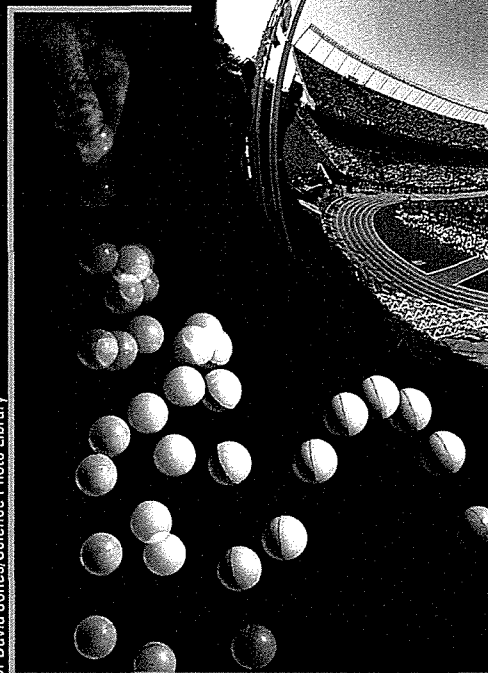
A high-speed photograph of the coronet (crowned) within a drop of water falls into a liquid. Such a shot is captured with a 1/25,000 second flash, triggered by the sound of the water drop.

M Funk/Image Bank



Tony Stone Photo Library, London

The 'explosion' effect – here of a cycling race – is used to create a feeling of speed. It is produced by zooming a variable focal length (zoom) lens. In this case out during a slowish exposure of 1/30 to 1/60 second.



A fish-eye view of an athletics stadium. Typically, this circular image type of fish-eye lens has a focal length of 6 mm, a maximum aperture of f/2.8 and a field of view of 220°. The result is great distortion.

Tony Stone Photo Library, London

A multiple image shot of a bouncing ball. In this the shutter is held open and a high-speed flash is fired repeatedly.

Trails of car lights, in Mexico City, are achieved by means of a time exposure, leaving the camera shutter open for several minutes.

Tony Stone Photo Library, London



Q AIR CASTORS

Q 'VARI-LIGHTS'

Q SOUND EQUALIZER

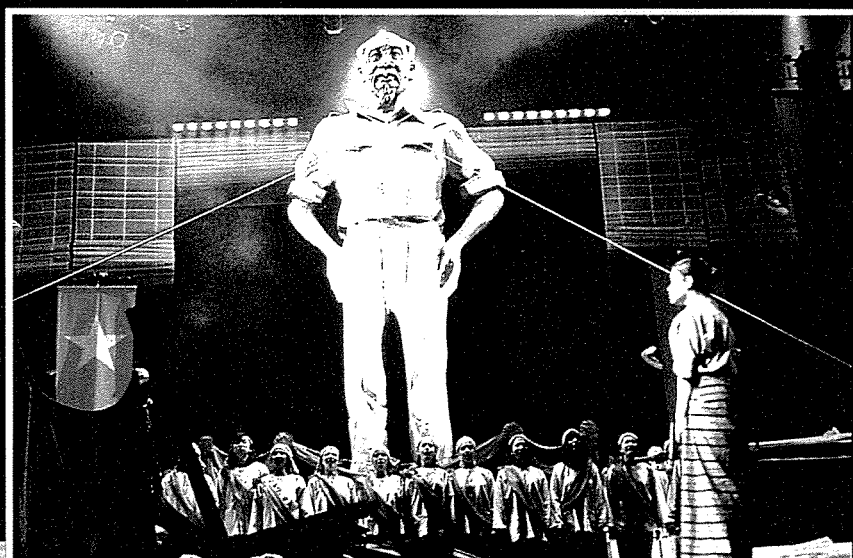
BACKSTAGE

SPECTACULAR SCENERY AND special effects are all part of the thrill of a modern stage show – thanks to advances in theatre lighting and sound technology.

While many theatres still rely on brawny stage hands to move scenery, big modern shows use more advanced methods. There are essentially four ways of getting pieces of scenery on to and off the theatre stage:

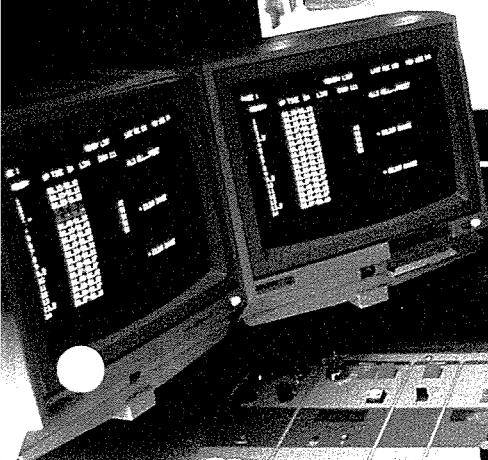
- It can be pushed or pulled on from

A 10-metre high statue of the Vietnamese leader Ho Chi Minh is hoisted on to the stage during the London-based production of the musical Miss Saigon



Michael le Pogor Trench

Computerized lighting boards can memorize each lighting change, fading groups of lanterns up or down at the required rate.



the wings (the sides of the stage) or from the rear on 'trucks' (wheeled platforms)

- It can be 'flown in' on steel cables from the area above the stage (the fly-tower)

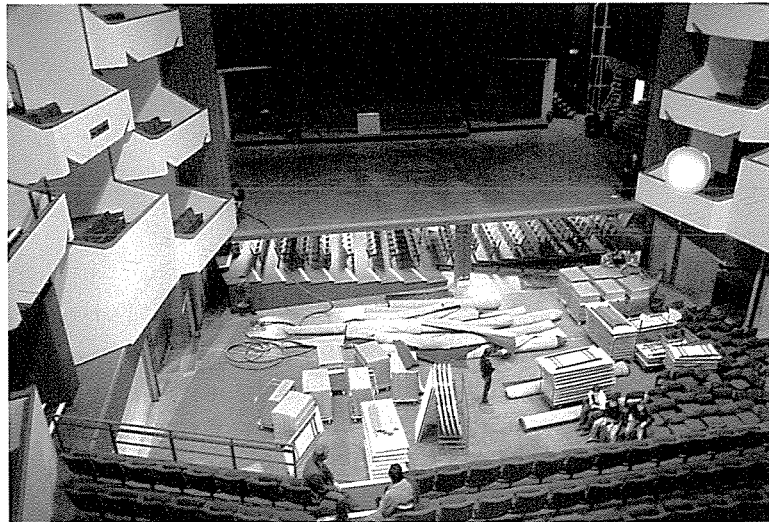
- Solid pieces of scenery can be placed on revolving sections of the stage to reveal different aspects of the set

- Scenery can be raised from below stage on movable sections.

Large, three-dimensional pieces of scenery are 'flown in' or 'trucked' on from the wings using electric winches and steel cables. A false floor is laid on the stage to keep the

Revolving stage 'wagons', like this one at the Lyttleton Theatre in London, are used for transporting heavy scenery on to the stage.

The 1500-seater Derngate Concert Hall in Northampton, UK, can be adapted for opera, ballet, drama, rock shows – even snooker matches. The seating is mounted on wagons that can be moved on air castors and stored under the stage. The walls of the theatre can be moved and re-settled in different positions, so changing the shape of the auditorium.



responding change. To co-ordinate such movements a central computer is used to control the operation of all the winches. This ensures that no snagging or fouling takes place in the understage tracks or up in the fly-tower. The computer stores in its memory the exact distance that each cable should move at each cue or change in the show. At the touch of a button everything moves precisely

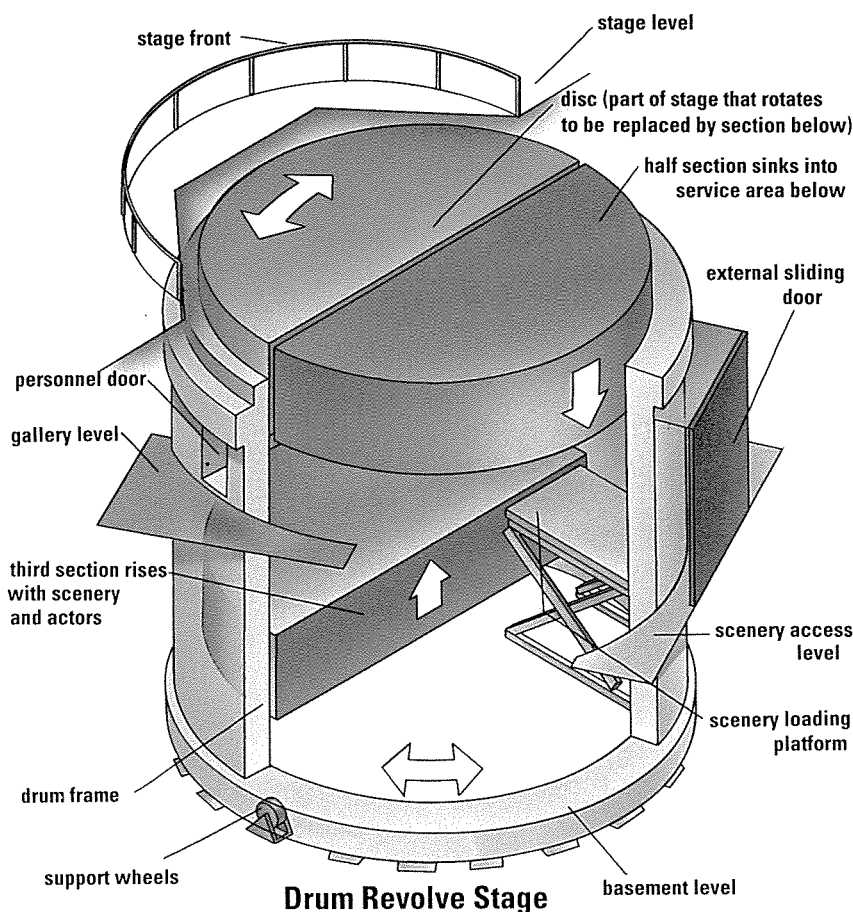
into place – or should do.

There are other problems, too. Steel cables, which support the pieces of scenery, expand and contract according to the temperature. These changes have to be monitored and alterations made on the distance counters to avoid collisions.

Computer memory

The most up-to-date lighting boards also depend on computer memory for each change in the lighting. But an experienced operator is still vital. The stage-manager, who is usually positioned at the side of the stage, watches the show, often on a video

This revolving stage is built into the floor of the acting area. One half can be lowered to be replaced by a third section complete with new scenery.



Drum Revolve Stage



cables and tracks for the trucks completely hidden from the audience inside the theatre.

Raising and lowering large pieces of scenery through the stage is usually more complicated – often involving expensive excavation work underneath the theatre to accommodate bulky hydraulics.

The most advanced method of moving scenery on trucks is on so-called air castors. These allow large pieces to be moved on a cushion of air. When the pressure is turned off, the truck settles on the stage floor, anchored in place by its own weight.

Split-second timing

One of the greatest changes in production style has been the abandoning of the curtain. Scene changes now usually take place in full view of the audience at great speed. Split-second timing is required so that two separate pieces of scenery being lowered from the fly-tower and trucked in from the wings fit together precisely, while the lights make a cor-

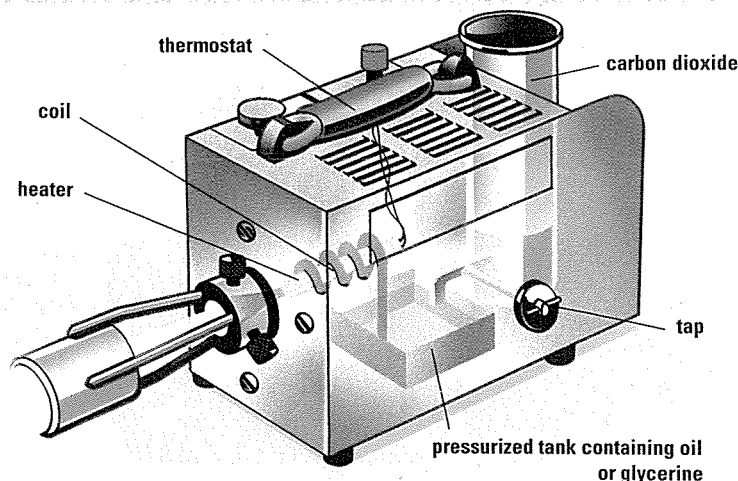
screen. He or she calls out each cue over an intercom to the stage-crew, lighting and sound operators. Stage men will have every lighting cue marked in a script.

Lighting cues

At that point the computer takes over. Each cue may require a series of light changes – fade-ups, fade-downs, colour changes and cross-fades – that would need an octopus to perform manually. But because the performance will vary from night to night, each cue is initiated manually. Otherwise, the computer might be pressing ahead, fading lights up or down, when the show has been brought to

Theatre Projects

SMOKE AND MIST ON THE STAGE



Stage smoke is produced with portable smoke machines or hand-held smoke guns. Oil, pressurized in its container, is forced around a heated, coiled tube where it turns into non-acrid, breathable smoke. For a rolling mist, dry ice (solid carbon dioxide with a tempera-

ture of -79°C) is usually used. When immersed in warm water, it produces a vapour that is heavier than air and billows across the stage floor. The warmer the water, the faster the vapour is made. Dry ice is super-cooled and must be handled with care, as it burns flesh.

John Houghton

Scenery hoist equipment consists of a number of motorized suspension hooks.

The hoists can operate together at a maximum speed of 2 metres per second, each carrying a maximum load of 200 kg. The controllers (right) sit in the fly-tower.



operate are actually fairly simple in construction. The simplest kind of lantern is a flood, which is simply a lamp and a reflector in a box.

High-intensity lights

Par-cans are small, low-voltage high-intensity lanterns with the reflector and lens sealed within the same glass envelope as the filament. These can be connected in series to make up the standard voltage, and have also been adapted as the so-called Vari-lights that are a relatively new introduction to the theatre.

Unlike normal lanterns, which are fixed in place on a horizontal bar or vertical boom, Vari-lights can move on a track, re-focus and change colour according to the requirements

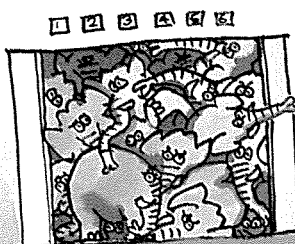
Royal Shakespeare Company/Barbican/Ray Duns

Royal Shakespeare Company/Barbican/Ray Duns

Just amazing!

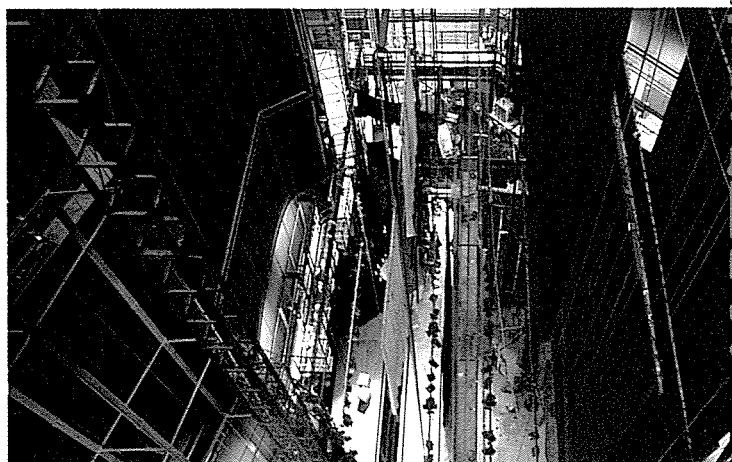
ELLY-VATED!

THE WORLD'S LARGEST THEATRE STAGE, IN NEVADA, USA, HAS 800 SPOTLIGHTS AND THREE ELEVATORS, EACH CAPABLE OF LIFTING 65 TONNES – OR 45 BABY ELEPHANTS!



Paul Raymond

The scenery hoist operator's view of the stage from the fly-tower. With modern mechanized systems, scenery of almost any size or shape can be 'flown in' at any angle. Each piece of scenery is counterbalanced by heavy loading weights.



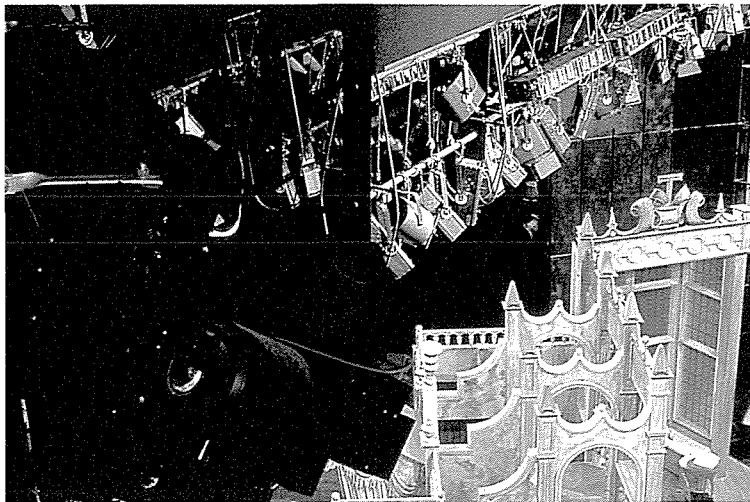
a standstill by a standing ovation!

The lighting operator sits at his board in a control box at the back of the auditorium, from where he can see what is going on. The lights – or lanterns – that he and his computer

of each new scene.

Many hundreds of these different types of lantern may be used to light a complicated scene. Most are hung above or at the side of the stage, but some can be seen shining from the





Theatre lamps – or lanterns – have to be used at varying levels of intensity and in different groups. 'Fresnel spots' are used for lighting large areas of the stage, while 'profile spots' give a sharply defined image of any object within their focal range.

according to the acoustic created by the size of audience and the air temperature on a given night.

The computer-assisted mixer feeds the signals to the equalizer, then to an amplifier and loudspeakers suspended above the stage and stacked at the sides. Programmable delay units within the system are controlled cue-by-cue by the mixing desk computer to ensure that the loudspeaker reinforcement coincides with the singer's voice, wherever he or she may be on the stage. This is

Theatre Projects auditorium. From the back of the auditorium or sometimes from boxes at the side you will see powerful follow-spots being operated. Also known as 'limes' these are basically profile spots with a more sophisticated optical and mechanical design allowing illumination of the star or stars of the show, usually in a musical number.

Sound on screen

The other crucial element, especially in a musical, is the sound. The sound desk mixes the signals from the microphones on the stage and in the orchestra pit. The principal actors' or singers' voices are picked up by radio microphones. These are slightly larger than a matchstick and can be hidden in the actor's hair or clothing. They are connected to a small battery-powered transmitter, that is hidden in the performer's costume.

Nowadays the sound controller

The sound desk mixes the signals coming from microphones in the orchestra pit, from microphones at the front of the stage, which pick up actors' voices, and from radio microphones worn by the lead singers.



Royal Shakespeare Company/Barbican/Ray Duns

may be assisted by a high-speed analyser that gathers information from microphones placed in different parts of the auditorium and displays it on a screen.

The equalizer

This sound equalization system is called a SIMTM and allows for the adjustment of sound quality by means of an equalizer during performance. The sound quality can vary

essential in large theatres, where the sound from the loudspeakers can otherwise reach the audience out of sync with the singer.

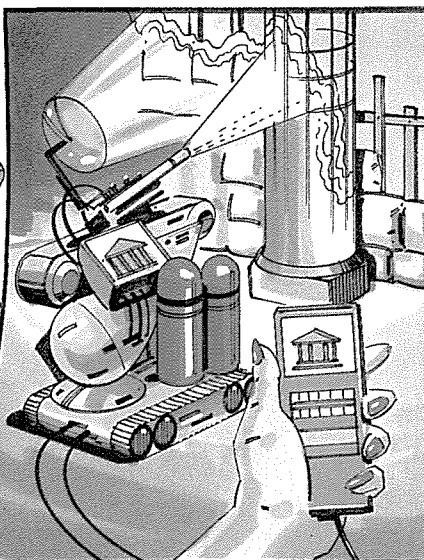
The sound operator also has control of any sound effects, which are pre-recorded then fed into the mixer as needed from a tape recorder. This may include a facility to stop the tape at the end of each effect – a light-sensitive cell is activated by light shining through a strip of clear tape.

INTO THE FUTURE

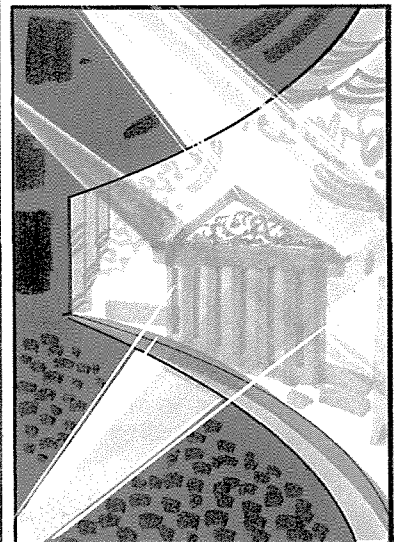
ON-SCREEN STAGE SETS



▲ When picture libraries become available on computerized data bases, set designers will be able to access any image worldwide via their domestic phone-line.



▲ Three-dimensional sets will then be constructed direct from a computer design by a process using layers of liquid plastic which solidifies under UV light.



▲ Holograms beamed on to the stage will replace conventional painted sets and make slide projection equipment a thing of the past.



ULTRASOUND



LOAD CELLS



STANDARD UNITS

WEIGHTS AND MEASURES

SINCE ANCIENT EGYPTIAN times, instruments for measuring lengths, weights and angles have remained much the same. Now though, with the advent of the microchip, a new generation of 'smart' tools has been developed.

For thousands of years the spirit level was a device that checked whether a surface is horizontal or vertical using a bubble floating in a coloured spirit in a small bottle, or vial. The level was placed on or against the surface to be checked. If the bubble came to rest between the two guide marks, the surface was flat and horizontal or vertical.



Checking angles

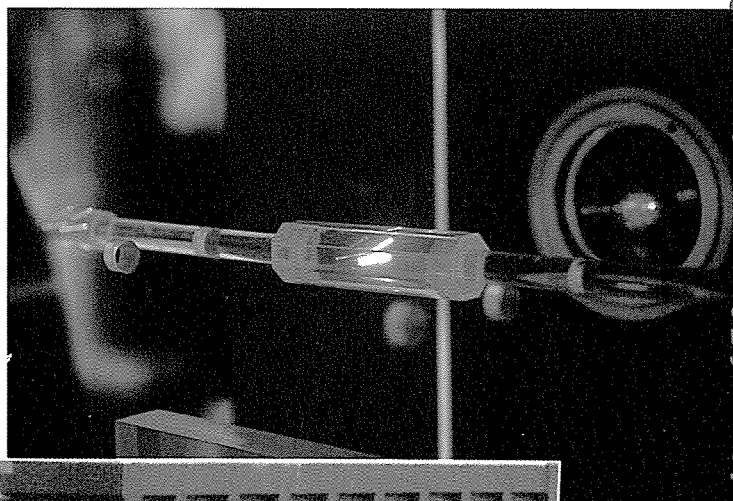
The curvature of the top edge of a vial is designed to give the instrument the required sensitivity - the distance the bubble travels for a given angle of tilt.

Modern spirit levels are accurate to better than one twentieth of a degree. Some have battery-powered lamps built in to light up the vial, while the microchip versions are able to check a variety of angles.

Measuring tape is often made of steel, protected by coatings of clear

plastic. It is curved to make it more rigid so that it will support itself when a length is unwound from its reel. Alternatively, it may be made of fibreglass threads embedded in plastic. In Europe, good-quality tapes carry a mark showing that they conform to a European Community accuracy

A weigh bridge is used to weigh large lorries and their loads. At the other end of the scale, a laser device (right) is used to measure the size, shape and number of tiny cells in a liquid sample. Calculations are made from the way laser light is scattered.

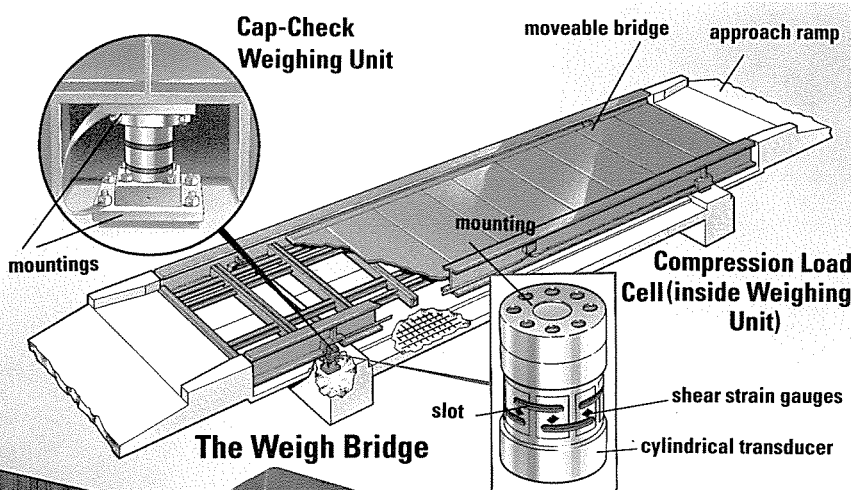


Mettler-Toledo Ltd



Jerry Mason/Harwell Laboratory/SPL





The Weigh Bridge

Inside the cap-check unit, the walls of the load cell's transducer has slots in it, so it deforms when weight is applied. Strain gauges measure the distortion. The readout is passed to the operator's hut (left).

without having to stretch out a tape measure. Surveyors now use an ultrasound distance estimator to measure rooms. This 'electronic tape measure' sends out a pulse of ultrasound – high-pitched sounds too shrill for the human ear to hear. The device picks up the echo from the far wall of the room and calculates the distance from the time it takes for the sound to make the round trip.

False readings

An ultrasound device can also be used, for example, to measure the distance across a busy street. However, accuracy is guaranteed to only 1 per cent – or 30 mm in three metres – making it much less accurate than a tape measure. There is also a danger of getting a false reading from a stray echo of something other than the object you are aiming at. This can be avoided by using a slightly more sophisticated ultrasound device which has a remote 'transponder'.

A transponder is a device that detects the ultrasound signal and sends back its own signal on a different frequency. It is placed against the object to which you are trying to measure the

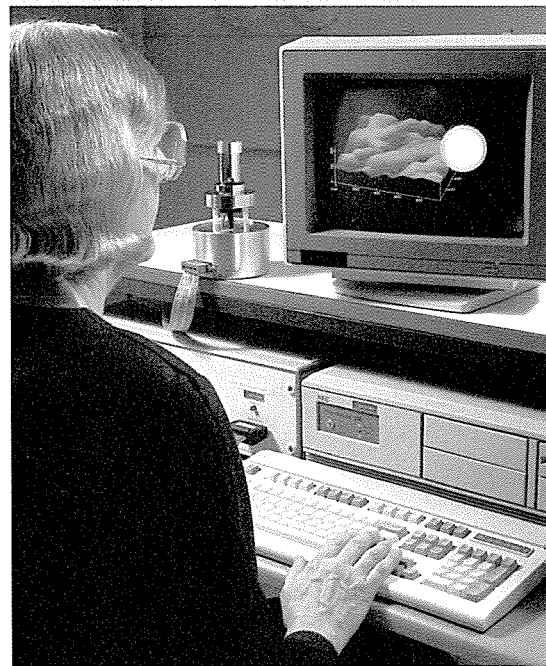
distance. The ultrasound device can then tell the difference between the new sound sent back by the transponder and a stray echo from a different object that has the same frequency as the original pulse.

Electronic balance

Similarly, in the laboratory, old-fashioned scales have been replaced by the electronic balance. This has a pan that is attached to a coil of wire. When the object to be weighed is placed in the pan, the pan goes down. An electric current is sent through the coil, turning it into an electromagnet. A permanent magnet inside the device repels the electromagnet, resisting the pan's downward movement. The heavier the object, the greater the current that must flow to bring the pan back to its original position. The current is measured and converted into a weight reading. A laboratory balance can be accurate to a tenth of a milligram and can normally weigh up to 250 gm.

More rugged weighing machines are used in shops, company dispatch rooms, food-packing rooms and on the factory floor. These machines

MEASURING ATOMS



The scanning tunnel microscope is not really a microscope at all, but a measuring device – a profiler that can measure details on the surface of a semiconductor down to one millionth of a millimetre across. The tip of a very fine wire is moved very close to the surface of the sample to be studied and electrons 'tunnel' between them. By moving the wire up and down, keeping the 'tunnelling current' constant, fine details of the surface can be resolved. The scanning tunnelling microscope can pick out individual oxygen atoms absorbed on the semiconductor's surface and pictures of such fine details can be built up.

standard. A Class II tape, for example, is guaranteed to be accurate to within 1.1 mm in three metres.

'Digital rule'

Today even the ruler can have a microchip built in. The 'digital rule' extends telescopically from one metre to up to five metres. The length is shown on a digital display. The user can switch between metric and imperial units at the press of a button. Accuracy is guaranteed to plus or minus 1 mm, comparing well with conventional tape.

It is possible to measure distances

Accurate weighing is vital when mixing paint commercially. Each batch must be exactly the same shade as the last. Electronic scales are used to weigh the neutral-coloured paint base before the pigment is added.



In a spirit level, when the bubble falls between the two lines, the surface is flat and level. That is how they have worked for thousands of years. Modern microchip versions tell the user how far out of true the surface is.

from cranes or attached to the forks of a lift truck. They can be read from a distance by an operator using a hand-held infra-red control unit.

'Base' units

All modern scientific units are defined in the *Système International*. There are seven SI 'base' units from which the other units can be worked out.

- The unit of length is the metre. It was first defined as one ten-millionth of the distance from the North Pole to the equator along a line through Paris. Then it was defined as the distance between two marks on a metal bar kept in a laboratory in Paris at constant temperature and atmospheric pressure. Now it is defined as the dis-

Micrometer



Precise measurement is given by screws and nuts milled to within 1.2 thousandths of a millimetre, allowing measurements down to 0.01 mm.

Paul Williams

tance light travels through a vacuum in a 1/299,792,458th of a second.

- The unit of mass is the kilogram. The 'prototype' kilogram is a block of platinum-iridium alloy kept in Paris
- The unit of time is the second. This

fed to an electronic scale, which instantly tells the user the total weight in either imperial or metric units at the press of a switch.

Dispatching

Sophisticated weighing machines will also show how many items there are on the pan and the cost of dispatching them by road, rail, courier or mail so the user can 'shop around' for the cheapest service at the touch of a button. The cost information is kept up to date by plugging in a new memory card whenever rates change.

Vehicles such as lorries or railway locomotives can be weighed by being driven on to a weigh bridge or platform that is mounted on several load cells. In factories, scales can be hung

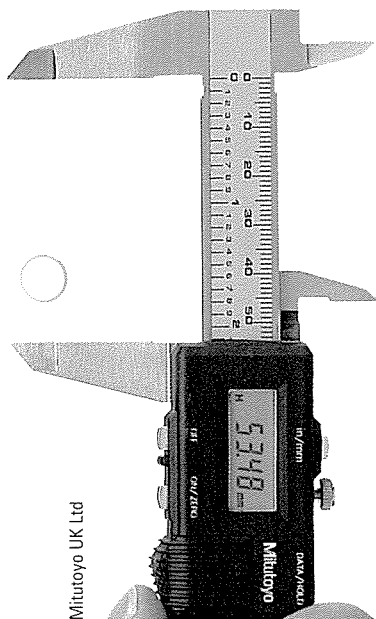
Electronic calipers can measure widths down to 0.02 mm and the output can be fed direct to a recording unit. Some are even solar powered.



Paul Raymond



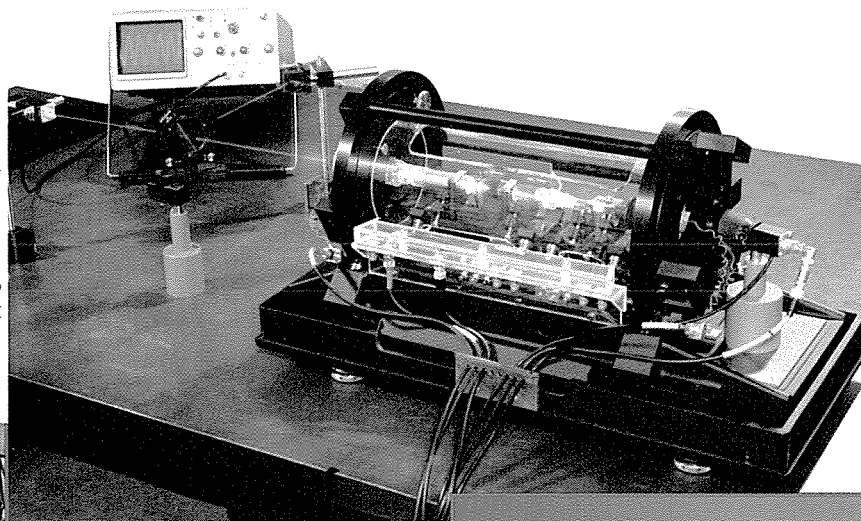
A Assid/ZEFA contain a 'load cell' - an aluminium or steel component that is bent or compressed when a load is placed on the scale. A 'strain gauge' attached to it generates an electric current - its size depends on how much it is compressed or bent. The current is then



Mitutoyo UK Ltd

was defined as 1/86,400th of the time taken by the Earth to rotate once, but the Earth's rotation time was found to vary by as much as a thousandth of a second throughout the year, so the second is now defined as 9,192,631,770 vibrations of a certain radiation given out by caesium-133

- The unit of electric current is the ampère, or amp. This is defined by the electromagnetic force it generates
- The unit of temperature is the kelvin. When water is at its 'triple point' – the temperature and pressure



Time is defined by a caesium clock. Atomic clocks are the most constant in the world, accurate to one thousandth of a second a year. The standard metre is fixed by laser light (above), while the prototype kilogram (right) is a block of platinum-iridium alloy kept in Paris.



Bureau International des Poids et Mesures

at which ice, liquid water and water vapour can all exist, which is practically the same as its freezing point – it is defined to be at a temperature of 273.16 kelvin. Zero kelvin is 'absolute zero' – the lowest temperature theoretically possible. 1°C is the same as 1 kelvin, but the Celsius (centi-

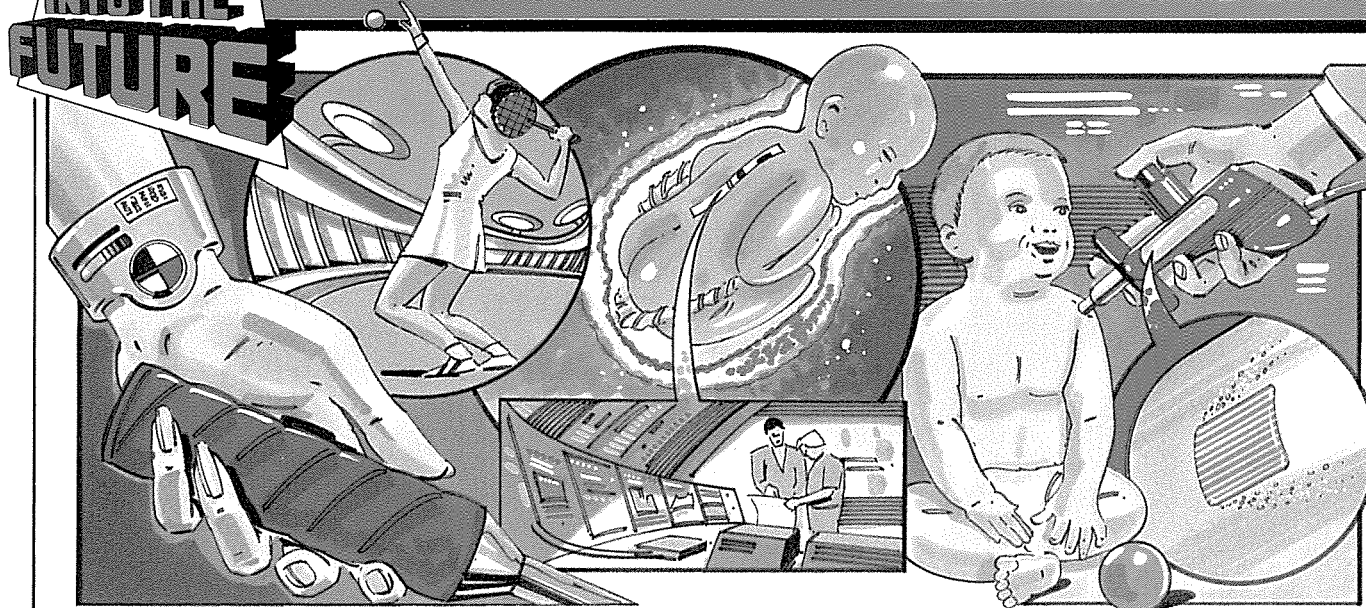
grade) scale starts from the triple point of water, which is 0°C

- The unit of luminous intensity – the intensity of light – is the candela. It is based on the amount of light given off per second by melting platinum
- The unit of the amount of any substance is the mole. This refers to the number of 'elementary entities' –

atoms or molecules. There is one mole present if the number of entities equals the number of atoms in precisely 12 gm of carbon-12. This number is approximately 602,300 million million million.

INTO THE FUTURE

MEASURING FOR HEALTH



▲ The dieter of the future will have a constant weight readout from a device worn on the wrist. This will work out their weight from their movements.

▲ The development of a foetus will be checked by a highly sensitive device attached to the growing baby inside its mother's womb.

▲ Constant monitoring of the body functions of a growing child will also be possible so that health and development problems can be spotted early.

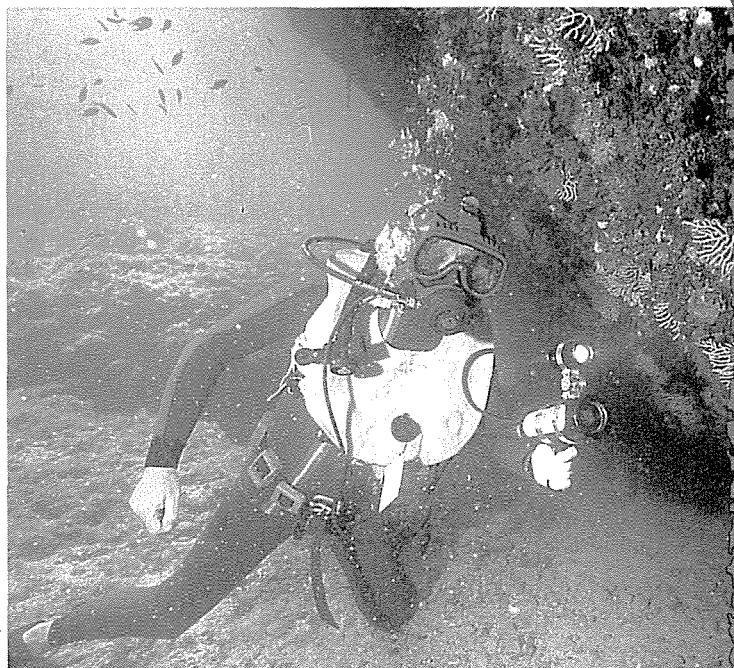
CAMCORDERS

VIDEO RECORDERS AND video cameras have brought about a revolution in home entertainment. Families can now enjoy pre-recorded films, record 'time-shift' television programmes that are broadcast at an inconvenient hour and even create their own home videos.

At the heart of the video revolution is the home video cassette recorder, or VCR. This works by running a 12.7 mm-wide plastic tape, coated with iron oxide, in front of a number of polished metal heads. The tape is contained within an oblong video cassette.

Recording heads transform the electronic signals coming from the

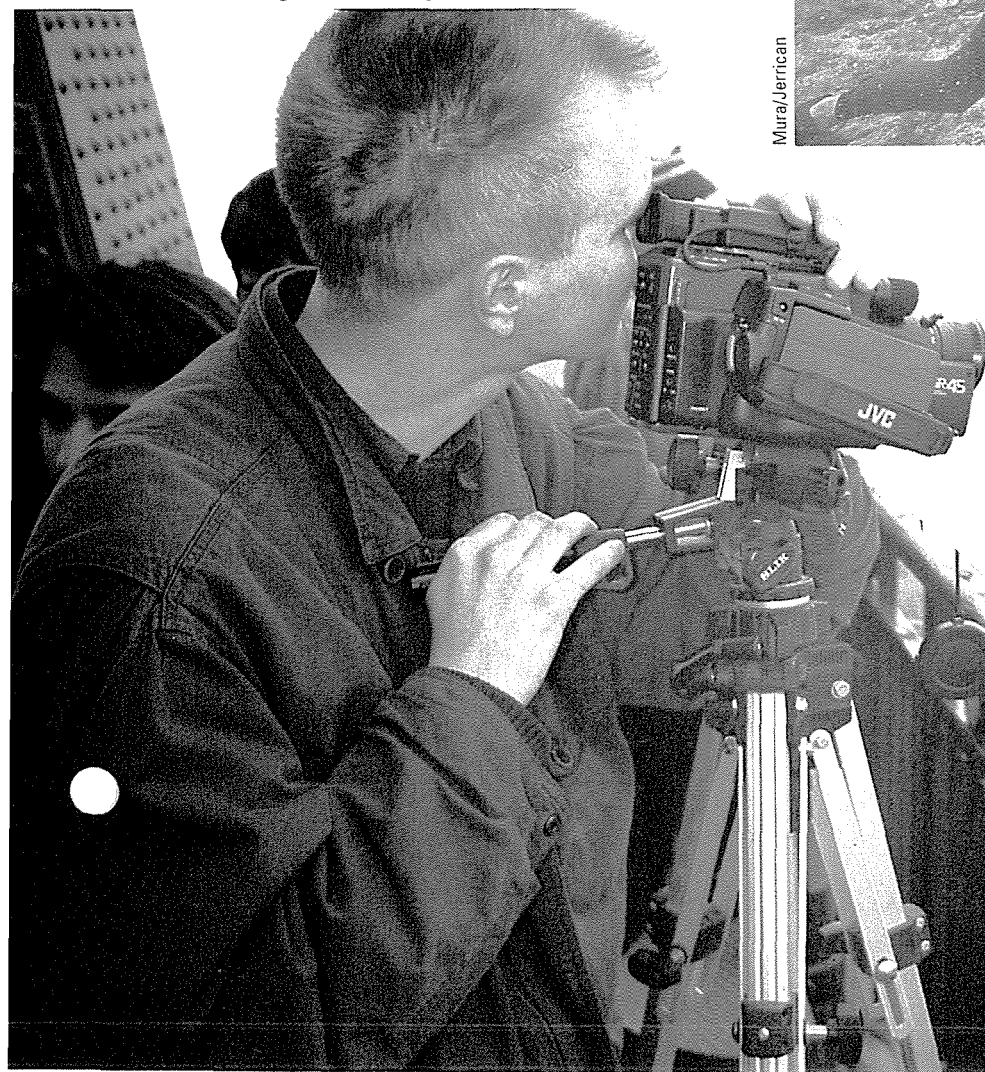
This cameraman is taking part in a French project designed to educate school children about marine life. His pictures are being recorded and simultaneously transmitted live to a study room from where the children can ask him questions via a telephone link.



Mura/Jerrican

Camcorders can store picture sequences in their digital memory. These can later be edited and combined with other recorded pictures to make a home movie.

television set into magnetic pulses that are stored in the iron oxide on the tape. The sound signal is laid down in a thin strip near the edge of the tape by an audio head. If a similar method were used to record picture information, it would take 100 km of tape just to hold a one-hour programme. So to avoid this problem, a rotating head drum containing two video heads records the picture signal in a series of long, diagonal tracks across the tape. When the tape is re-wound and played back, the heads read the magnetic pattern



The Canon Still Video Camera

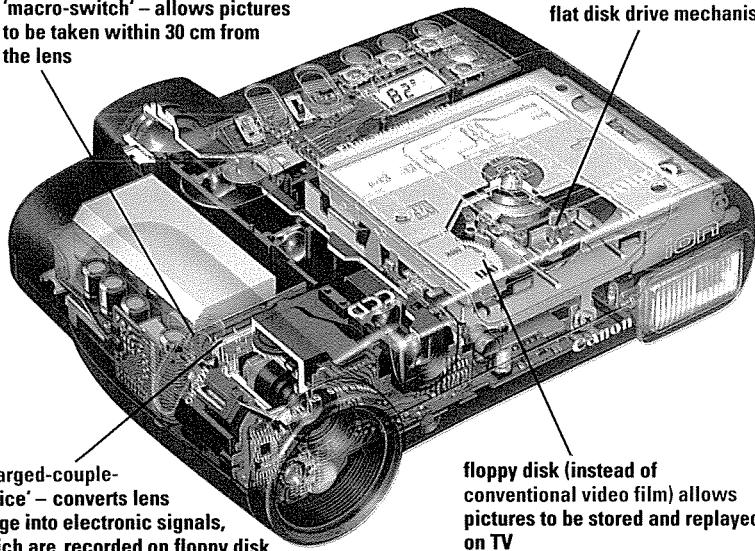
'macro-switch' – allows pictures to be taken within 30 cm from the lens

flat disk drive mechanism

'charged-couple-device' – converts lens image into electronic signals, which are recorded on floppy disk

floppy disk (instead of conventional video film) allows pictures to be stored and replayed on TV

Canon (UK) Ltd



and convert it back into an electronic signal to be sent to the television set.

The VCR is connected to a TV by a single cable. In this way, broadcast signals, picked up by the TV aerial, are passed on to the VCR even when the television is switched off. The VCR is equipped with its own receiver so that it can tune into any of the incoming channels. This allows, for instance, a programme on one channel to be viewed 'live', while the VCR records a programme being broadcast simultaneously on a different channel.



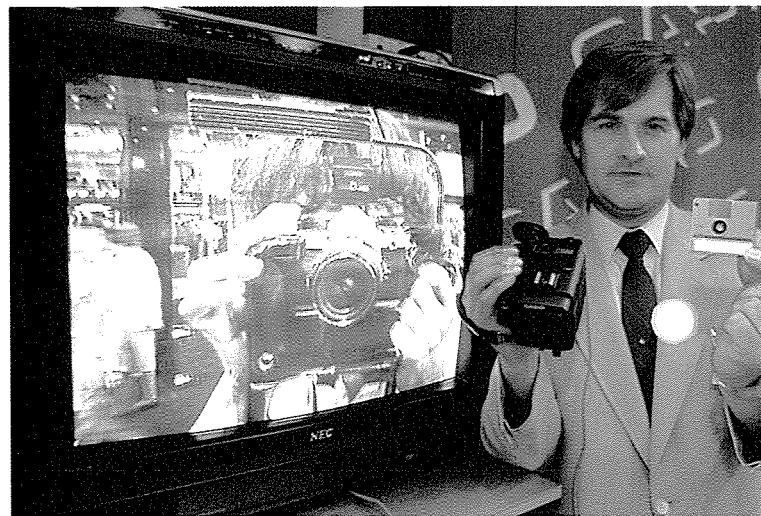
Advance recording

A timer enables the VCR to be set in advance to record a programme at any hour of the day or night. Most models now can be programmed to record a number of different programmes up to a week in advance.

Other features commonly found on today's VCRs include fast picture search, slow motion, freeze-frame and frame-by-frame advance, all of

Computer disks are starting to replace film in still cameras.

The disk can record up to 50 pictures, which means that the photographer can store thousands of shots in a space far smaller than is needed for conventional prints or transparencies.



which control the speed at which the video is played. Finally, more and more VCRs are being equipped with facilities for making home movie-making easier.

Using a portable video camera it is now possible to record pictures and sound of everyday events directly on to video cassette tape. In some cases, the camera is connected to a separate VCR, either a standard model or a portable one powered by batteries. So-called camcorders, however, have the camera and recorder built into a single unit for easy handling.



Scanner

A boom microphone attached to the camera picks up the sound while a vidicon tube behind the camera lens scans the picture with an electron beam and converts it to an electrical signal. The main controls are the aperture for varying the amount of light entering the camera, the focus and the zoom.

Certain features on VCRs help the amateur to edit home-made videos. An automatic start-edit control, for example, gives invisible joins between

picture frames when the tape is stopped and started. An audio dub control allows sound, such as a piece of music, to be superimposed on a previously-recorded video.



Tape counter

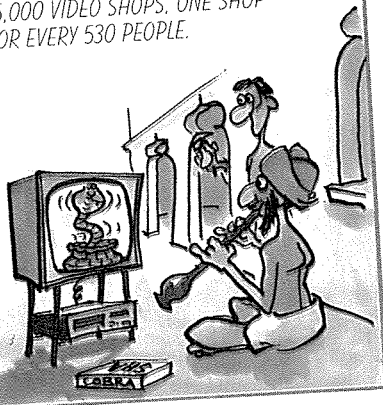
To do more sophisticated editing, two video recorders are needed with leads connecting their video out/in and audio out/in sockets. The original tape is viewed using one machine and the parts to be edited noted down with the help of the tape counter. Then the original tape is played again on VCR 1 while the new tape is recorded on VCR 2, using the start-edit control on VCR 2 to cut down on

Still video cameras contain a tiny 'charge-coupled device'. This converts the image from the lens into electrical signals, which are recorded magnetically on a floppy disk. The pictures can be replayed on TV.

Just amazing!

SQUARE EYES!

THE MOST VIDEO-SWAMPED CITY IN THE WORLD IS BOMBAY, INDIA, WITH 15,000 VIDEO SHOPS. ONE SHOP FOR EVERY 530 PEOPLE.



Paul Raymond

the distortion otherwise generated.

Among the latest developments in home video technology are VCRs that can record up to 15 hours of programmes on a single tape. This is done by running the tape at 0.78 cm per second, instead of the usual 2.34 cm per second, thus increasing the recording density. Video recorders will soon be available that can tape high-quality digital stereo sound along with the pictures.

VCR CONTROL UNITS

Most VCRs now come with a hand-held remote-control unit. This sends signals to the VCR via an invisible infra-red beam. A person using the unit simply presses the appropriate button, say, to begin recording from a certain channel, and this command travels as a coded infra-red message. Inside the VCR, a sensor, tuned to the precise frequency of the remote control, picks up the signals and translates them into electronic pulses. A decoder chip recognizes the pulses and sends a signal to carry out the command.

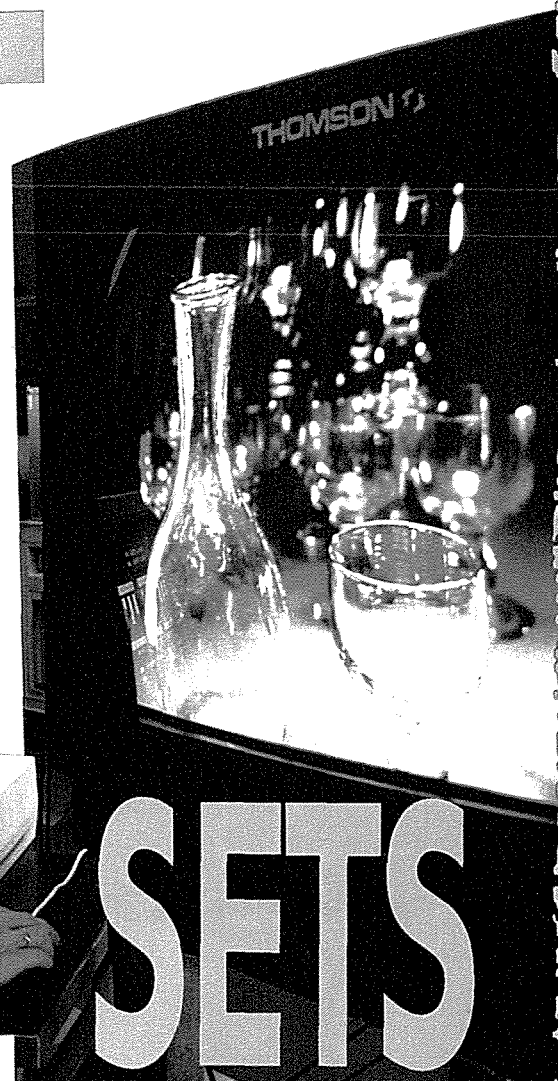
Gamma/Frank Spooner Pictures



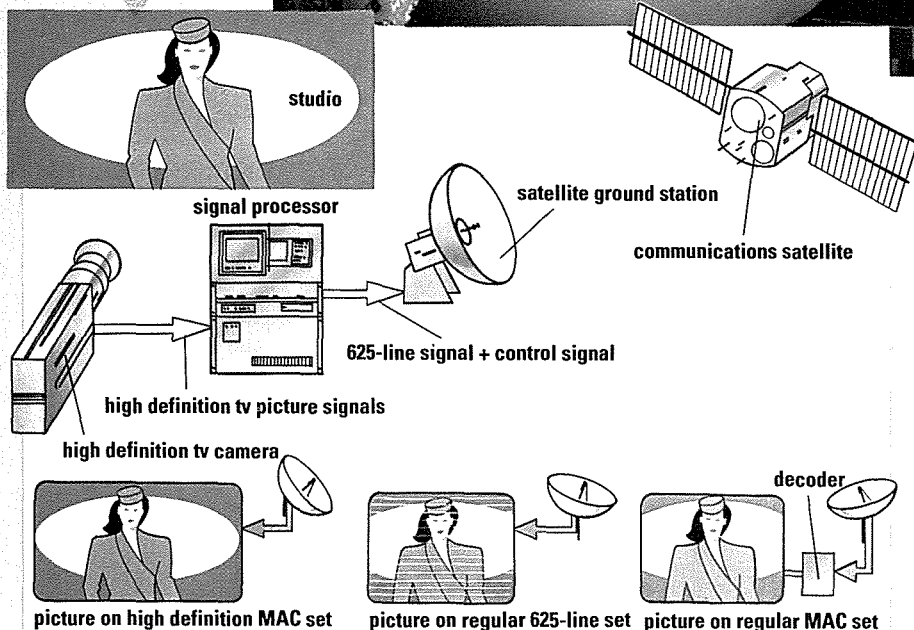
SMART

A technician uses a personal computer to adjust the picture on an experimental French high definition television set. HDTV will not be broadcast in Europe until at least the year 2000.

Current MAC high definition TV systems which are being developed will give true wide-screen HDTV, an enhanced picture on a regular MAC set and be available to viewers with normal TV sets.



SETS



screen width to height. So the aspect ratio of new televisions in Japan has been increased from 4:3 to 5:3, making them wider and better for showing films.

European countries, meanwhile, are trying to agree on their own standard for HDTV. One system being considered would double the number of picture lines from 625 to 1,250 and increase the aspect ratio to 16:9.

Extra information

Improving the picture quality, however, means that the television signal has to be sent out at higher frequencies to carry the extra information. The problem is that the higher the frequencies, the wider the bandwidth or spread of frequencies. Present-day televisions use a bandwidth of 6 megahertz (6 million waves per second). Using the same technology, wide-screen televisions with over 1,000 lines would need a bandwidth of between 25 and 30 megahertz. This is impossibly high in today's overcrowded airwaves.

To reduce the bandwidth for HDTV, computers will be used to transform the high definition picture leaving the studio camera into digital code. The computer will map the pic-

FUTURE TELEVISION SETS will have clearer pictures and wider screens thanks to a new development called High Definition Television, or HDTV.

The number of horizontal lines on a TV screen limits the picture quality. Most of Europe, Africa, mainland Asia and Australia use the PAL standard - this has 625 lines. That number will be doubled in the next decade.

The United States and Japan use a different standard, known as NTSC, which has 525 lines. In Japan, more than 10 years of testing various types of HDTV has led the country to adopt a standard of 1,125 lines.

Wider pictures

Studies have also shown that most viewers would prefer screens with a higher aspect ratio - the ratio of

Philippe Plailly/Science Photo Library



High Definition TV gives a noticeably better picture than the current 625-line system (far right). With double the number of lines, HDTV no longer shows the scan lines the picture is made up from. So far broadcasts are restricted to Japan.



Sony Broadcast & Communications

ture and log just the parts that are changing. The digitized picture will then be converted into two parts.

The experimental European HDTV system uses a conventional analogue 625-line image and one digital control signal that contains information about the picture content.

The control signal is transmitted in

the same way as Teletext, that is in the unused picture lines that form a thin black border at the top and bottom of the screen. The HDTV set will use the control signal to process the accompanying analogue signal. This enables the bandwidth for transmitting HDTV signals to be cut from 25 megahertz to 12 megahertz, which can be handled by regular satellite transmission. In 1992 the Olympic

No great leap of technology is required in the studio to produce High Definition Television. The problems come when the extra picture data has to be broadcast.

Games were broadcast in parts of Europe on HDTV. However, in 1994 technical production difficulties emerged which would make domestic sets extremely expensive and the project was suspended.

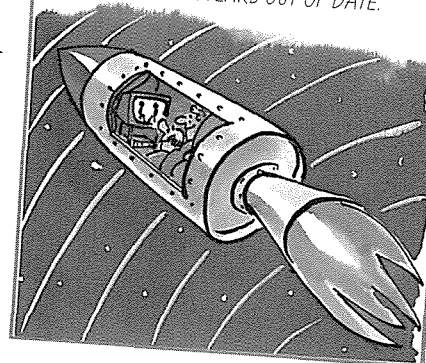
American Success

An American project is being developed by a combined effort of

Just amazing!

SOAP STARS

TV SIGNALS TRAVEL OUT INTO SPACE – SO ALIENS NEAR BARNARD'S STAR, 5.9 LIGHT YEARS AWAY, WILL BE WATCHING NEIGHBOURS SIX YEARS OUT OF DATE.



Paul Raymond

AT&T, General Instrument, the Massachusetts Institute of Technology, Zenith Electronics and other companies. The research team undertook experimental broadcasts in North Carolina in 1994. It is hoped that improvements developed as a result of these tests can be swiftly implemented and a final package developed for tests by late 1995 or early 1996.

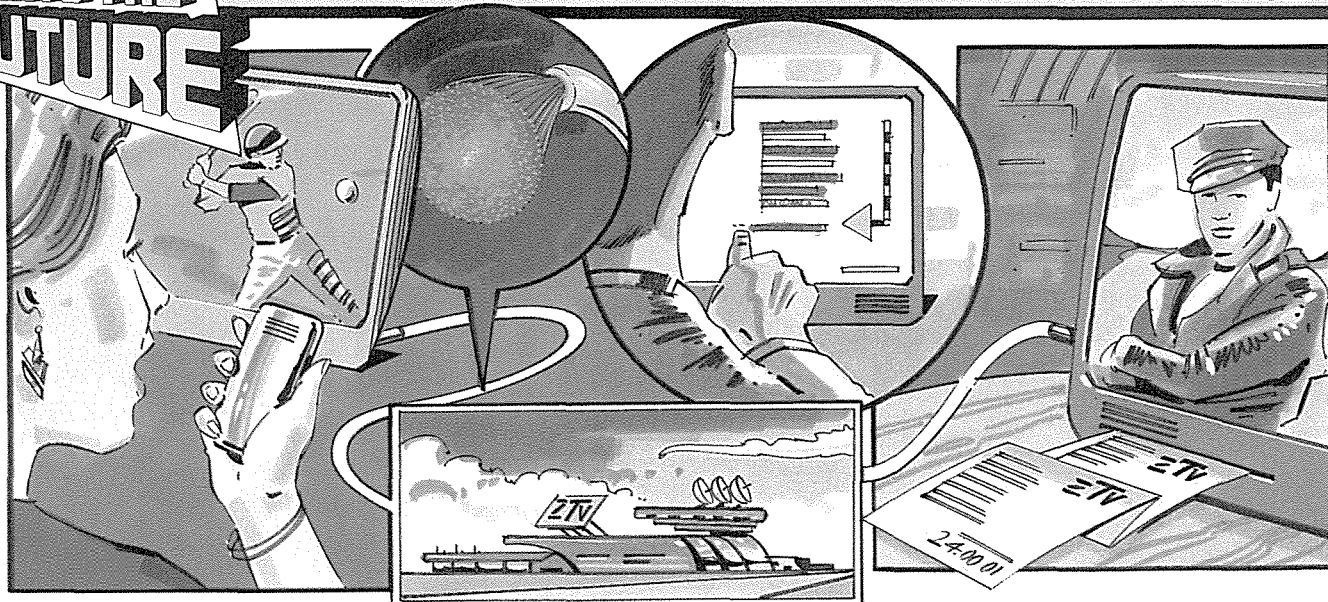
Rather more successful is PAL-Plus which enables wide-screen movies to be transmitted via existing networks. Several TV stations transmit movies via PAL-Plus. On ordinary TV sets the picture appears as a 'letter-box' with black bands above and below the picture, but on PAL-Plus receiving sets the picture is enlarged to fill the entire screen using coded instructions in the black bands.



Sony Broadcast & Communications

INTO THE FUTURE

REMOTE CONTROL



▲ A TV remote-control with no buttons. Ask to see a film or TV show. The request is sent by infrared link to the set, then via fibre-optic cable to the TV company.

▲ There your request is fed into a voice-recognition unit. On recognizing your request, the system may transmit a message back, asking for further details.

▲ The system retrieves the programme from a digital store and transmits it to your set. A record is kept, so you can be billed at the end of the month.

Joe Lawrence

 TORQUE CONTROL

 ANGLE DRILLS

 ALLIGATOR SAWS

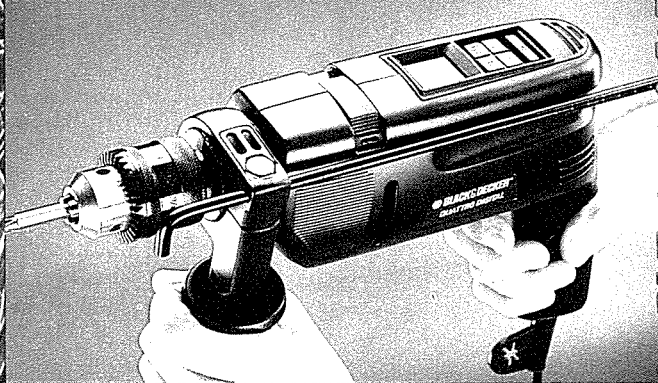
HAND POWER

WITH ELECTRIC POWERED drills, saws and screwdrivers at their elbows, the modern carpenter, plumber and builder can work faster and their amateur counterparts can easily achieve craftsmanlike results.

Over the last few years, there has been quite a revolution in electric drills and other power tools. Old-fashioned tools had long trailing wires that were potentially dangerous — there was always a risk that they would be cut or damaged. Many new power tools have rechargeable batteries built-in so that they can be used remote from any power source.

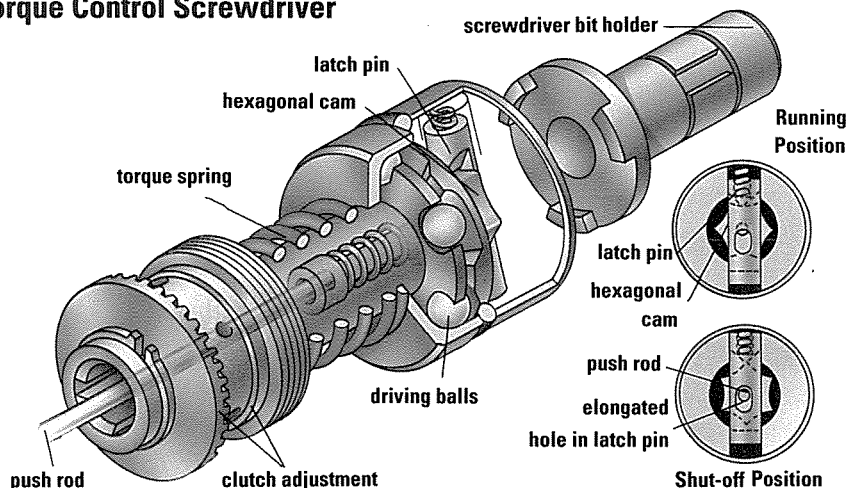
A drill operator can now key in information about the material to be worked upon. The drill will then select the right speed and power needed to

Grinders. Power compressors are used to spray paint on aircraft wings. Modern hammer drills have electronic controls that select the correct speed automatically. A memory facility ensures that the machine repeats the setting precisely for repetitive screwdriving or drilling jobs.



Torque Control Screwdriver

Desoutter/Mark Franklin



Some electric screwdrivers have different clutch control settings. These allow the operator to vary the degree of torque (twisting power) according to the task in hand.

An 'environment-friendly' chain-saw. A catalyzer reduces the amount of noxious hydrocarbons in the exhaust gas by 80%, and the chain is lubricated by a synthetic oil that decomposes on the forest floor within three weeks.



complete the job and will confirm the appropriate settings on a small liquid crystal display screen!

Most drills now boast 'hammer action' for drilling into masonry. The

hammer action knocks the drill bit back and forth while it is turning, literally hammering the bit into the brick or stonework.

Electric drills are now reversible, so that the bit can easily be extracted if it is stuck. And if the drill also has 'torque control' this means it can also be used as a powered screwdriver. Torque control sets a limit on the amount of twisting force the drill will provide so that it will stop turning when the screw is driven fully home. Small purpose-built electric screwdrivers have become popular.

Tough tips

Most modern drill bits are tipped with super-hard tungsten carbide – as are the blades of power saws. This gives them a longer life before they blunt.

The new alligator-type of saw is taking over from small chain saws for domestic use. Instead of a chain being pulled around the edge of the blade by a petrol engine, the electrically powered alligator saw has two straight blades with serrated edges. The blades cut by moving back and forth in opposite directions.

Although these are set to take over some of the work of small circular saws, the circular saw still has the advantage that the blades can be set to a precise angle and depth.

Jig saws, which are used to cut precise patterns in flat surfaces, now incorporate scrolling – the blade alone can be turned without turning the whole saw. Modern jig saws also contain a blower system to blow dust away from the cutting line so that the operator can see what he is doing.

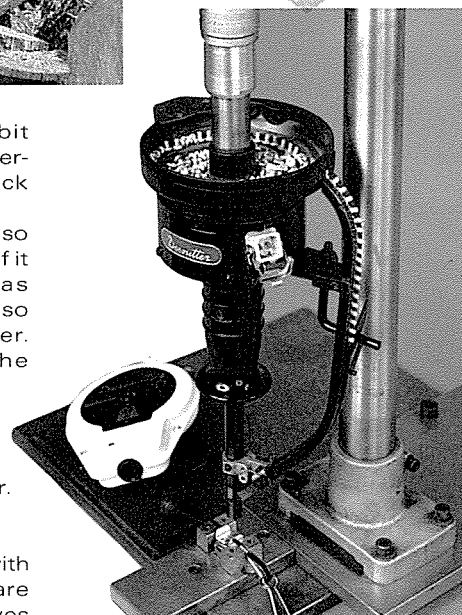
Vacuum cleaning

Dust is even more of a problem with sanders. But the latest sanders have a vacuum-cleaning system built to suck up the dust produced when working through holes in the base.

Another useful invention in the home DIY area is the steam wallpaper stripper. This works a bit like a steam iron. It forces jets of steam through the wallpaper to soften the paste underneath, allowing the paper to be peeled easily off the wall.

Electric power tools are rarely used in industry because of the risk of electrocution and sparks causing a fire. Pneumatic tools are much safer. These are connected to an air hose and powered by air at a pres-

An electric screwfeeder – used in the manufacture of a wide range of products – feeds the screws automatically to the driving head, ready for fastening.



Desoutter

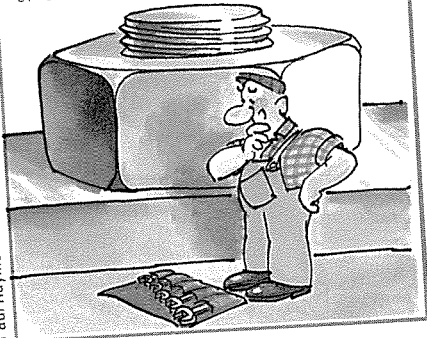
sure six times greater than normal atmospheric pressure.

In industry, precise tools are required for precise jobs. As well as straight drills, where the bit points directly out of the front, you will find angle drills where the drill bit is at right angles to the body of the drill so holes can be drilled in tight corners.

Just amazing!

NUTS

THE WORLD'S LARGEST NUTS – 'PILGRIM NUTS' – WERE MADE FOR A LARGE FORGING PRESS. EACH IS 132 CM IN DIAMETER, WITH A THREAD OF 63.5 CM AND WEIGHS 4.7 TONNES!



Paul Raymond





AIR TURBINE DRILLS



ULTRASONIC SCALERS



X-RAYS

DRILLS 'N' FRILLS

PROCEDURES FOR FILLING AND extracting teeth have changed little in recent years, but sophisticated tools are making the dentist's life a lot easier.

One of the greatest advances in dentistry has been the development of the high-speed air turbine drill. The drill bit - or bur - is mounted in a chuck that sits on a tiny turbine. The hand-piece is connected to an air hose and the compressed air flowing past the turbine spins the drill at 250,000 to 500,000 revolutions per minute.

Although the drill spins very fast and cuts through tooth enamel quickly, the power of the compressed air drive is very low - allowing the bit to halt rapidly if it hits an obstruction. The exhaust air also cools the tooth and water sprayed through the drill washes out the debris.



Amalgam

The final preparation of a cavity is done with hand tools. Small chisels with stainless steel or tungsten carbide tips are used to cut the margin of the cavity and excavators are used to scoop out the decayed dentine.

Dental amalgam is used for most fillings. This is a mixture of metals - mostly silver with some tin, copper

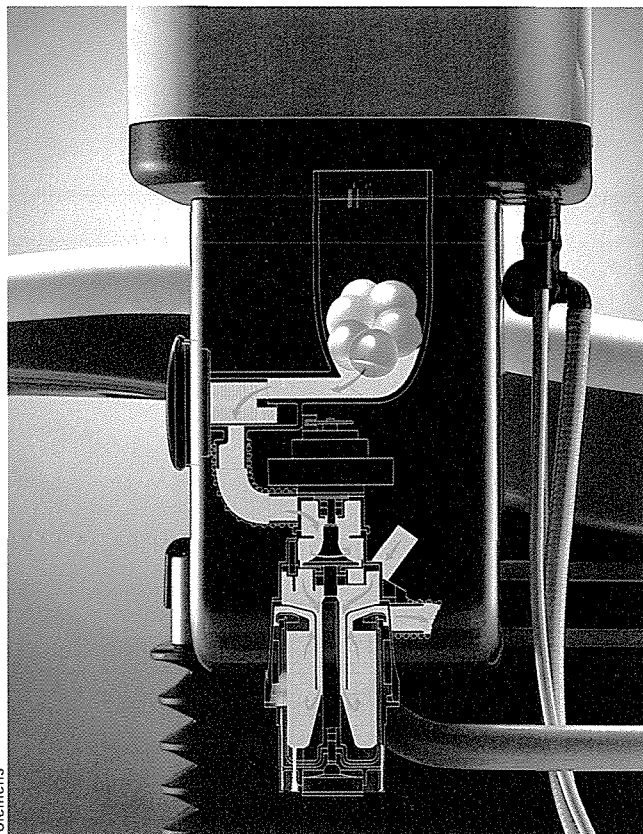
The latest electronic treatment unit allows the dentist, with finger-touch control (below), to programme instruments, adjust the position of the patient and even refill the water tumbler.

Siemens

SIEMENS

Sirona M1



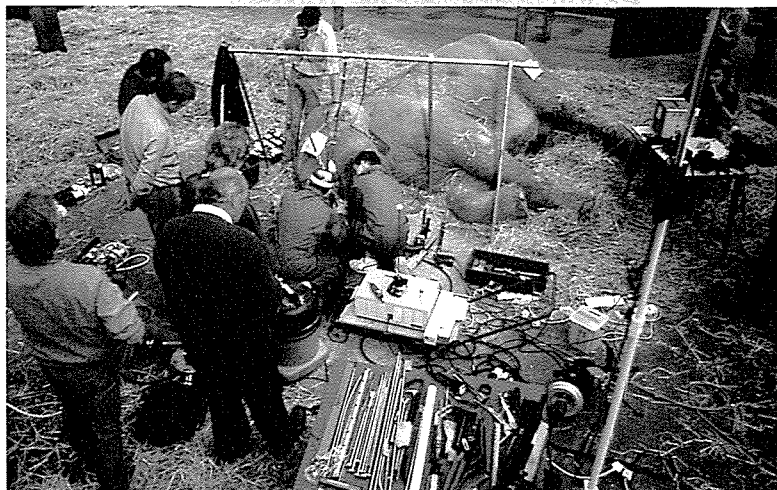


An environment-friendly automatic separating system traps over 95% of amalgam and mercury spat into the cuspidor (sink) by patients having work done on fillings. A rotating ball cleans the internal system walls automatically.

ANIMAL DENTISTRY

Extraction of an infected elephant tusk requires highly specialized tools and instruments – usually designed by animal dentists themselves. Such an operation may require four dental surgeons, and two vets to administer anaesthetic. The scaffolding shown is used to help the retraction of tusk sheath or cheek. Zoo animals often suffer dental decay as a result of eating the sweets and sticky buns thrown to them by visitors.

Peter Kertesz



and zinc added – softened by mercury. The mixing is done mechanically in a 'vibrator'. The soft paste produced is put into an amalgam carrier and forced into the cavity. A plugger compresses the amalgam and a carver shapes the surface. The finish is smoothed with a burnisher. The dentist has only a few minutes to smooth and shape before the amalgam becomes hard enough to bite on.

The operating light that hangs over the patient's chair usually incorporates a rigid quartz rod or flexible fibre optic light guide. This is

used to 'cure' the light-sensitive white filling materials used in front teeth. The light output is filtered towards the blue end of the spectrum as most light-activated materials respond better to blue light.



Tartar blasters

Also suspended above the chair is an X-ray machine. This is mounted on an articulated arm and can be pointed at the patient's mouth in any direction. The X-ray film is held in a plastic 'bite wing' holder clenched between the

Titanium instruments can be given a very smooth surface that will harbour few germs. The scanning electron micrograph (below) shows diamond grit embedded in a metal drill bur.

patient's teeth. Once exposed, it must be developed. Some dental surgeries have facilities to do this themselves.

In up-to-date dental surgeries, hand scalars have given way to air or ultrasonic scalars. Air scalars are like small pneumatic drills that hammer tartar (a hard deposit, mainly of calcium phosphate) off teeth. Ultrasonic scalars have a tip that vibrates at a high frequency. Both types of scalar dislodge tartar with a minimum of effort on the part of the dentist and give the patient only a slight tickling sensation. The energy expended, though, is so high that the tip must be water cooled, which has the added advantage of flushing away the debris.

Just amazing!

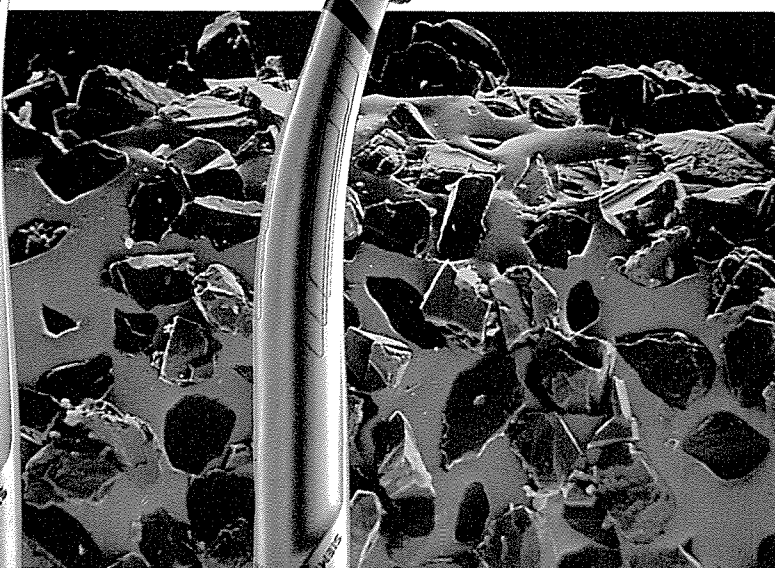
SEEING IS BELIEVING

TO PERSUADE PATIENTS TO CLEAN THEIR TEETH PROPERLY, SOME DENTISTS ENTERTAIN THEIR CAPTIVE AUDIENCES WITH BLOWN-UP PICTURES OF THE TARTAR SCRAPED OFF THEIR TEETH.



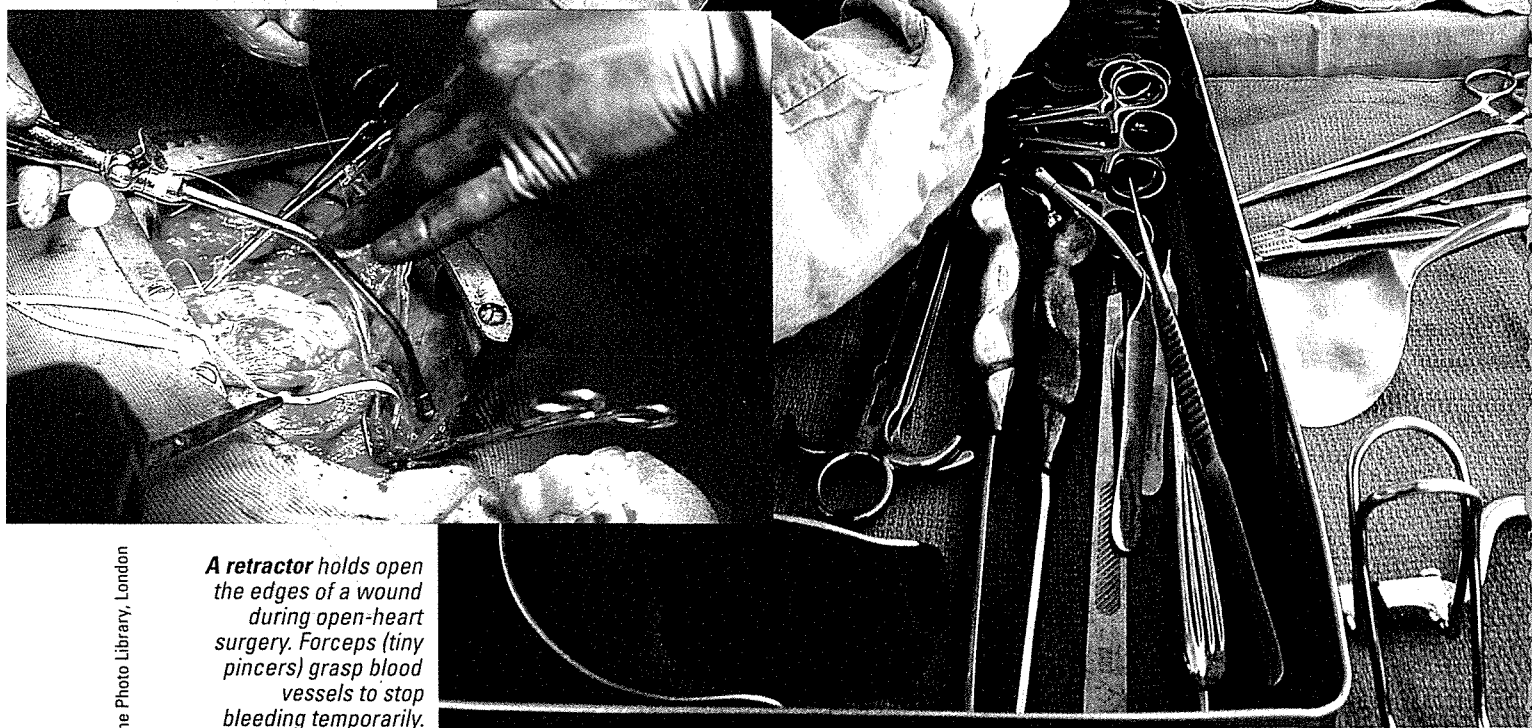
Paul Raymonde

Manfred Kage/Science Photo Library



- PERCUTANEOUS CATHETERS
- NEEDLES AND BLADES
- SKIN GRAFTS

NEW SHARP



A retractor holds open the edges of a wound during open-heart surgery. Forceps (tiny pincers) grasp blood vessels to stop bleeding temporarily.

Tony Stone Photo Library, London

THE LATEST ADVANCES in surgical procedures mean that surgeons are having to get used to a whole new generation of operating tools. These are smaller, lighter, more sophisticated and more expensive than ever before.

Some modern operations, such as sewing back a severed limb, are much more intricate and take much longer than traditional surgery and so surgeons need lighter instruments to work with to prevent fatigue. Many modern tools, made of the rare metal titanium, are less than half the weight of standard stainless steel tools.

Titanium is also more brittle than stainless steel, allowing it to be machined to a very fine point. This is vital for operations where nerves and tiny blood vessels are sewn together.

Microsurgery

Surgery on this scale – microsurgery – is performed under a microscope at 30 times magnification. Around even the smallest blood vessel there has to be at least eight stitches to make the joint blood-tight. The nylon thread used is no greater in breadth than a human hair and the minute needle has to be held by a titanium needle-holder – no other material can be worked to a

Sterilized surgical instruments are laid out in advance of an operation to save time. Sixty pairs of forceps may be used in a single operation.

fine enough point. Titanium tools, though, cost several times their stainless steel equivalent.

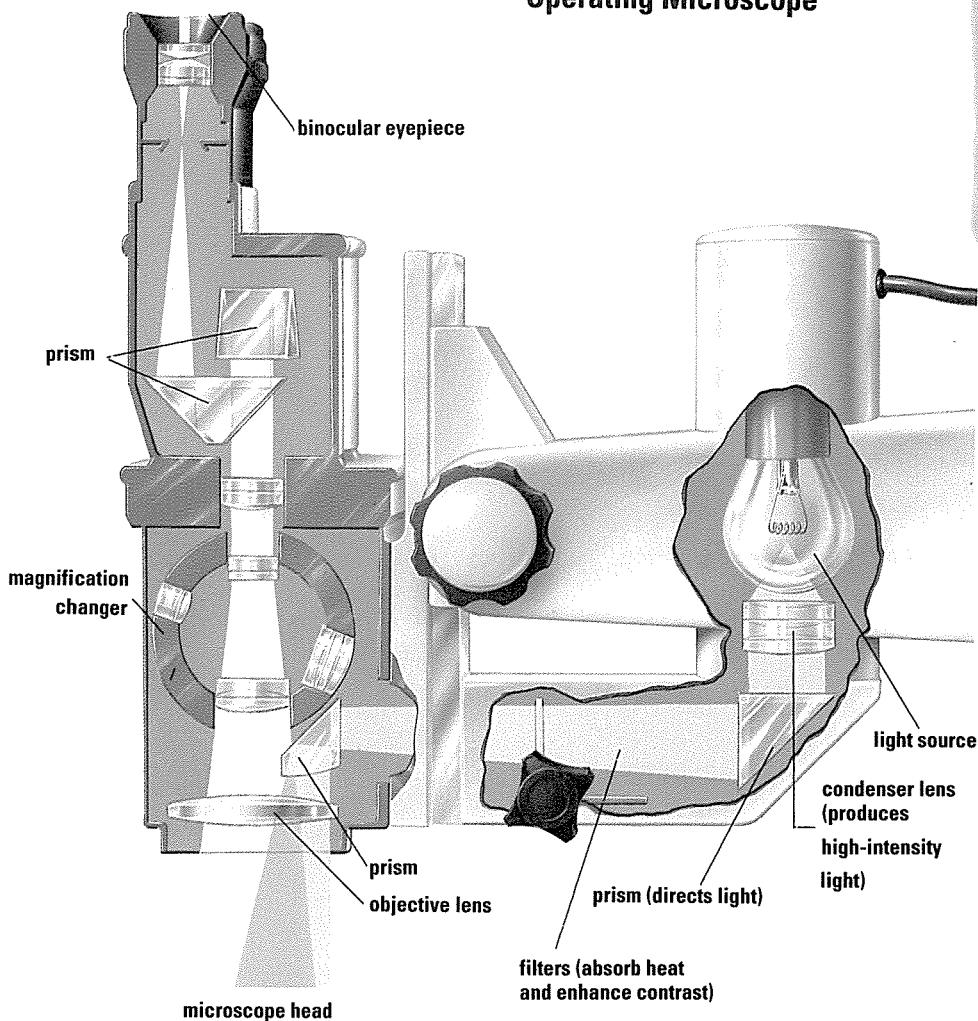
New metals

Tungsten carbide – the material used in modern drill bits – is used to line the insides of the jaws of forceps to improve grip and the cutting edges of scissors to improve wear. But, again, tungsten carbide is very expensive

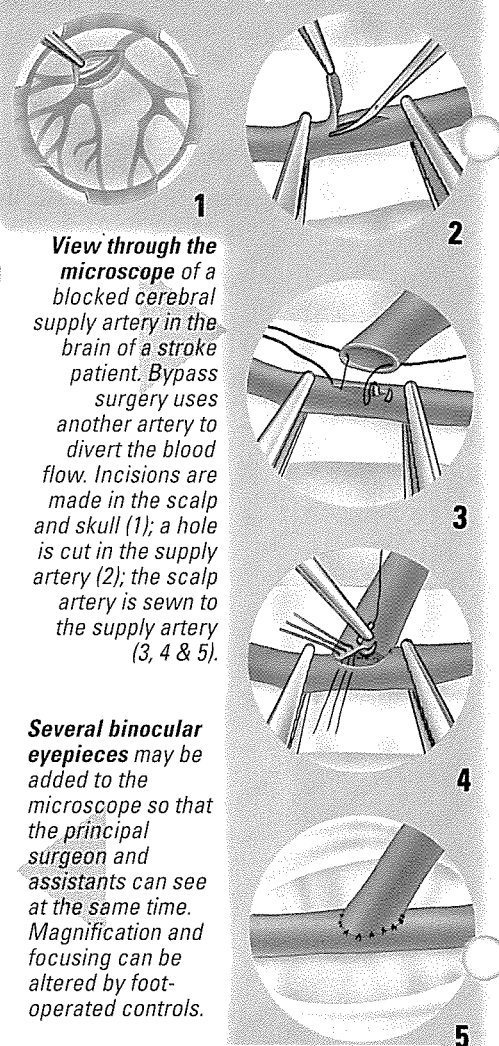
Tony Stone Photo Library, London



Operating Microscope



Artery Bypass



View through the microscope of a blocked cerebral supply artery in the brain of a stroke patient. Bypass surgery uses another artery to divert the blood flow. Incisions are made in the scalp and skull (1); a hole is cut in the supply artery (2); the scalp artery is sewn to the supply artery (3, 4 & 5).

Several binocular eyepieces may be added to the microscope so that the principal surgeon and assistants can see at the same time. Magnification and focusing can be altered by foot-operated controls.

Mark Franklin

compared to stainless steel.

The tools used with endoscopes – the flexible viewing instruments that can be pushed through the body's canals (see NEW TECHNOLOGY page 139) – are limited.

Flexible tools

All the instruments have to be less than 3 mm in diameter, long and flexible so that they can follow the body's natural tracts – the throat, bowel, urethral and genital tracts, and blood vessels. Essentially there are three types of instruments: tiny forceps grip and pull away unwanted tissue; minute electrodes put a current through tissues to burn them to seal blood vessels; and small balloons can be used to open blocked blood vessels and stuck heart valves.

Keyhole surgery

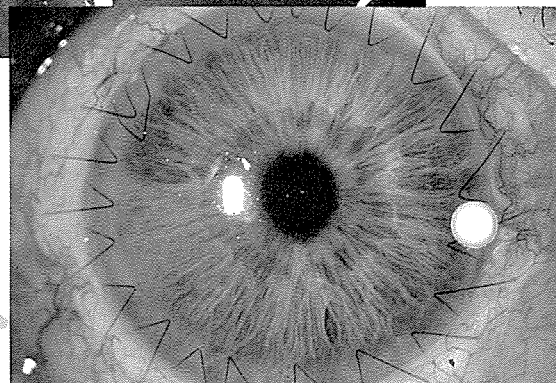
So-called minimum intervention or 'keyhole' surgery – where the surgeon operates through a small incision, rather than a large opening – has also meant that instruments have shrunk. Another development – percutaneous surgery – has seen them get even smaller. Percutaneous surgery is carried out through a tiny pin prick in the skin. Slipped discs in the back are operated on in this way.

Spinal discs can be compared to

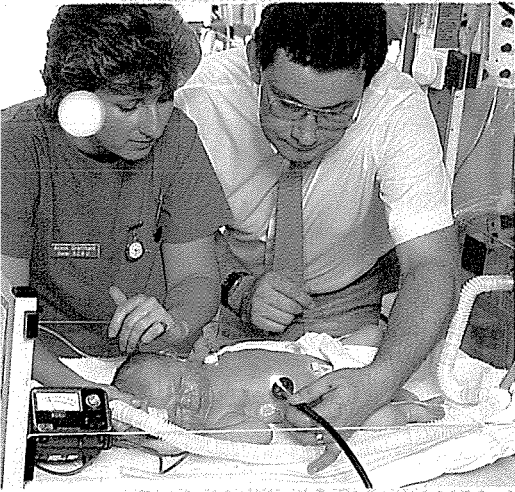


A surgeon's view through an operating microscope shows the connection of blood vessels. The free ends of the vessels are clamped (using ligatures) and stitched together.

The precision of eye surgery is aided by operating microscopes. Suture thread – no thicker than human hair – is mounted on needles only a few mm long.



SHADOWLIGHT

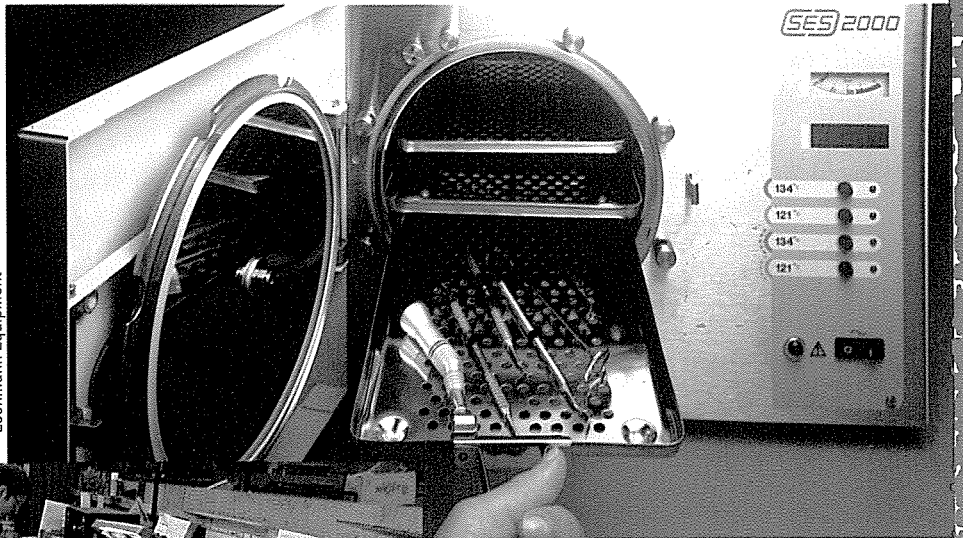


Downs Surgical

Because exposure to X-rays can harm tiny infants, surgeons, until now, have had to operate without their help. But a new diagnostic tool has changed all that.

A premature baby's skin is so thin, and its body so small, that a bright light held close to the skin illuminates its insides. Until recently, generating bright light meant generating heat too. Now the 'Shadowlight' keeps the hot light source at a safe distance from the baby by conducting its light down a long fibre-optic tube. The head of the tube is cool enough to press against the baby's skin while the light it gives off is bright enough to shine through its tiny body.

Eschmann Equipment



Of the many types of surgical instruments manufactured, most are used to cut tissues, hold them or suture (stitch) them together again. All instruments are sterilized in an autoclave (above) before use by heating them, via steam, to 134°C for 3 mins.



Downs Surgical

the hydro-elastic suspension in a car. Between each vertebra of the back there is a doughnut of cartilage surrounding a reservoir of fluid, which absorbs shock waves.

Slipped discs

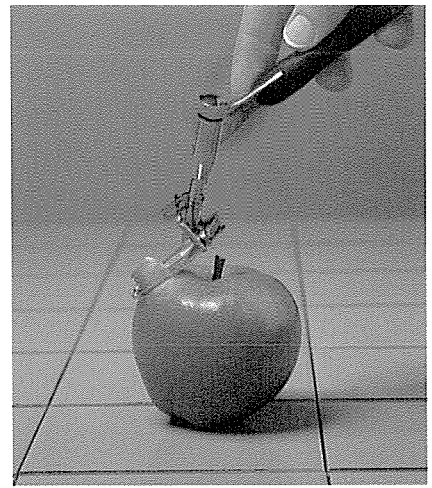
Discs do not actually 'slip'. The cartilage simply gets worn and the doughnut distorts and pinches a nerve ending as it emerges from the spine. It is difficult to locate which disc or discs are causing pain and exactly where the problem lies. In the past, a full-scale operation was performed on

the back – resulting in three months' recuperation in hospital for the patient. Nowadays percutaneous surgery can be performed on a patient under local anaesthetic. The surgeon probes with a 1 mm needle until he finds the point where the doughnut of cartilage is distorted. He or she then begins to slip a series of larger tubes over the needle to open up a gap of between 3 mm and 7.5 mm in diameter.

X-ray guides

Tiny retractors can then be pushed down the tube to pull the nerve ending out of the way and tiny burs are used to grind away at the bone, which may also be trapping the nerve. The doctor can see what he is doing on a series of X-rays taken while working

A minute trephine – tiny cutting tool – is then inserted to cut into the



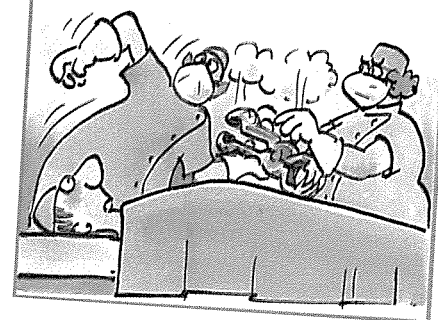
Downs Surgical

Dermatomes are used in plastic and reconstruction surgery to peel off thin layers of skin to the exact depth required.

Just amazing!

EYE OF A NEEDLE

ONE OF THE SMALLEST INSTRUMENTS USED IN OPTICAL SURGERY HAS A BLADE 0.2 CM IN DIAMETER. THE LARGEST SURGICAL INSTRUMENTS ARE ROBOTIC RETRACTORS WEIGHING 5 KG.



Paul Raymond

cartilage. A tube with a tiny Archimedean screw can also be inserted to drain off fluid and relieve pressure. When the two vertebrae collapse, they fuse together, leaving the patient a little shorter but no longer in pain.

Minimum intervention

The advantages of this type of surgery are many. Muscles and outer tissues of the body do not have to be cut. They are just gently forced apart by the series of small tubes. No blood transfusion is necessary and no





Lasers can be used by surgeons instead of scalpels. They have the advantage of being able to cauterize (reseal) small blood vessels as they cut them.

wounds require to be stitched up. Rather than spending three weeks in bed recovering, the patient can be back at work the next day.

Endoscopy

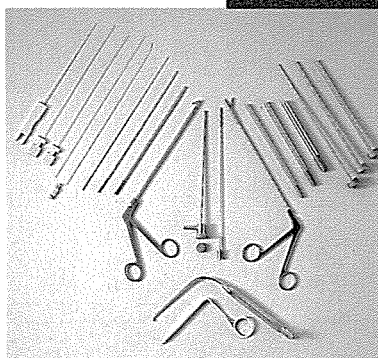
Percutaneous surgery can also be used on the knee and to remove kidney stones because the kidneys lie close to the skin. In percutaneous operations on the knee, two tubes are often used – one inserted from either side. Water is forced down one tube to open up the knee joint to give the surgeon a little room to work. An endoscope is pushed down the other tube so that the surgeon can see

exactly what he or she is operating on.

Unlike flexible endoscopic instruments, percutaneous instruments are rigid – often modified or scaled down versions of standard surgical implements. Indeed, many were originally designed for operating on the ear.

Plastic and reconstruction surgery is now widely practised – where skin

Percutaneous operating techniques require a range of specially designed fine tools. Using them in conjunction with X-rays, surgeons can now operate on, for example, a slipped spinal disc, through a tiny hole in the skin.

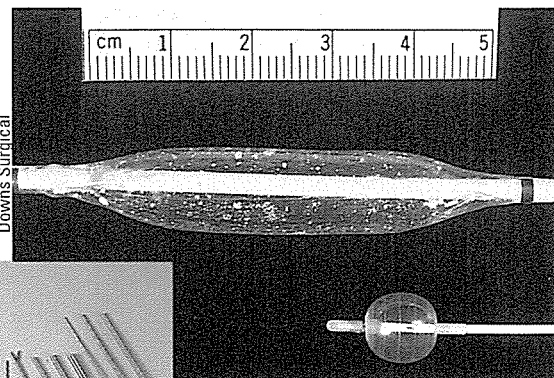


is cut away from one area for use in other parts of the body. A dermatome is the instrument used to peel off thin slivers of skin ready for transplanting. This is like a safety razor with the distance between the guard and the blade controlled by a micrometer gauge. This sets exactly the depth of tissue that will be peeled off.

Plastic surgery

The largest dermatomes have blades up to 200 mm long, with reversible handles so that they can be used to cut in two directions or by a left-handed surgeon. Smaller ones, the size of regular razors, are used for grafts on the fingers and tiny dermatomes using standard scalpel blades are used to shape, trim and tidy up the finished graft.

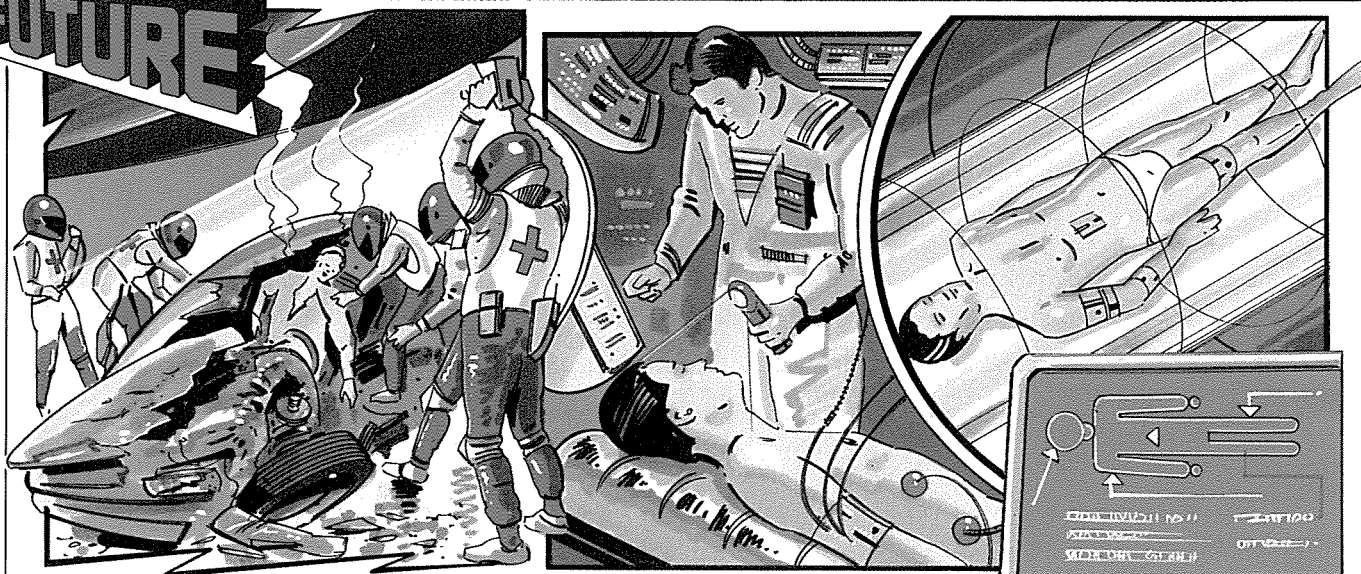
Science Photo Library



Balloon inflators, are used to unblock or widen arteries. Guided into place using enhanced X-ray images, balloons are then inflated to clear a way for blood to flow.

INTO THE FUTURE

THE INVISIBLE HEALING HAND



▲ Doctors of the future will have at their disposal a battery of non-invasive tools for both the diagnosis and treatment of injury and disease.

▲ In casualty a hand-held scanner will be used to pinpoint broken bones and damaged soft tissue, while body functions are watched by a remote monitor.

▲ Finally, while all but essential body functions are 'shut down', a molecular accelerator will be used to speed up the body's own healing processes.

Joe Lawrence

DESTRUCTION TESTING

CARS, SHIPS, PLANES AND BRIDGES - vehicles and structures of all kinds are tested to the limits of their endurance long before they ever reach the user.

Lives and millions of pounds of investment depend on their safe and efficient functioning. Costly programmes of testing begin with models in wind tunnels and water tanks, before risks are taken with the first prototypes.

Much can be learned about a car or lorry before it is ever built by simulating its behaviour on computers. But the final tests, normally to destruction, must be made on the real thing.

Assault courses

A well-equipped vehicle test track has a high-speed circuit, sharp bends and sections with different kinds of surface. There are also water-filled dips in

some places and steep ones that can be constantly played to test braking and steering in the wet. All kinds of road furniture are hazards for vehicles. There is even a machine to generate side winds.

Testing extends beyond performance and handling to the noisiness of the vehicle and the pollution level of its exhaust gases.

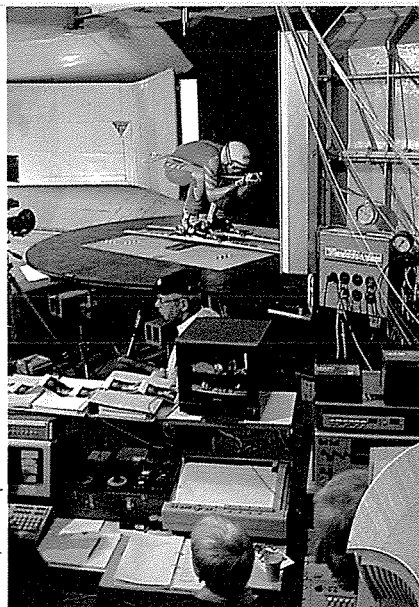
Crash recording

When a vehicle is test-crashed it is hauled along by cables. An impact-measuring device is mounted on the vehicle and the obstacle that it hits. Cameras filming at up to 10,000 frames per second capture every

Wind tunnels can simulate

adverse weather conditions. The swirling white snow on this model bridge is created by machines that generate

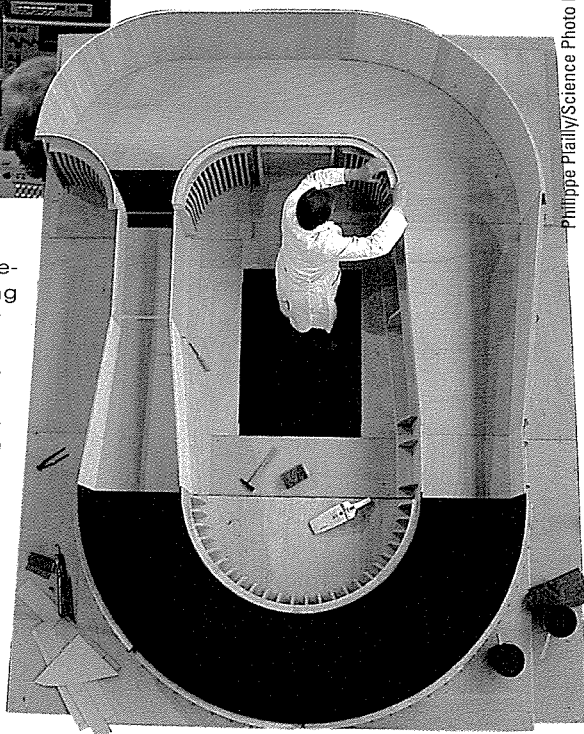




controlled model boats may also be taken to sea to be tried out in more realistic conditions.

Once a full-scale ship has been built, it must be subjected to sea trials. Its engine power is measured – both

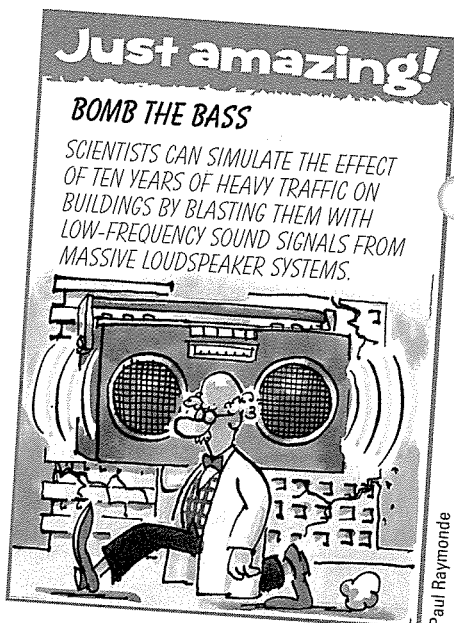
Professional downhill skiers use wind tunnels to assess the amount of wind resistance to their bodies, helping them to achieve faster speeds.



moment of the impact.

Test dummies are a specialized field of engineering in their own right. Their joints imitate those of a real person, so that the stresses and impacts experienced in a simulated crash are as similar as possible to those that a human being would experience in a real crash. Dummies are wired up with force-measuring devices in each area of the body.

Dummies are designed to precise specifications: a side-impact dummy (SID) is different from one used to test the effects of front and rear impacts.



when the ship is under way and when it is pulling against a fixed bollard. Its manoeuvrability must be tested – how small its turning circle is and how fast it responds to the wheel. Speed, roll, pitch and yaw are tested, under different sea conditions. A war-ship's noise-level must also be measured carefully, since this can give away its position to enemy submarines.



Computer monitor

There is a trend in all types of testing towards amassing huge amounts of computer data for later analysis. One function after another is taken away from human assessors. Even judging the smoothness of a car's ride can be done by a ride meter, a 'black box' that sits on a passenger seat recording the forces that it experiences during a test-ride.



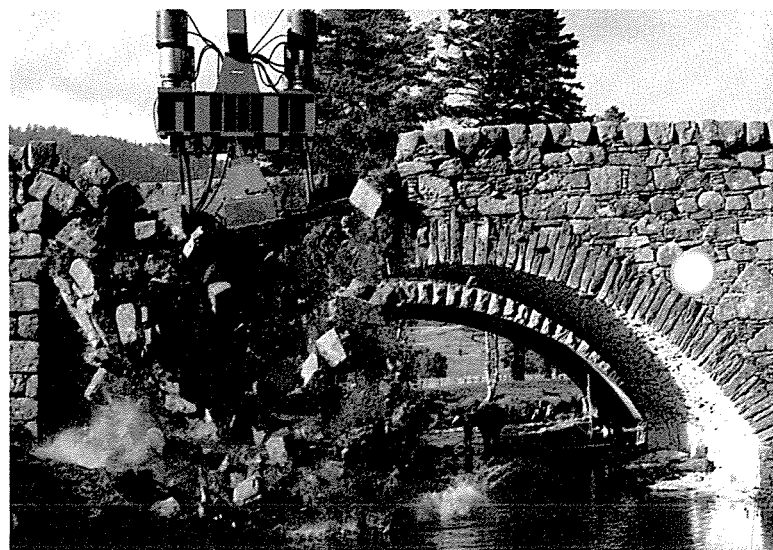
Test pilots

But human beings are still needed in testing. Test pilots, for instance, must not only be above-average pilots, they must also be good at maths and science. They must be able to analyse the behaviour of their aircraft and to give a clear written or spoken report on it afterwards. They must also be very versatile, since they will have to fly many different types of plane.

A wind tunnel under construction. Four metres wide and two metres high, the tunnel is capable of generating an air flow of 100km/h.

A test plane crash involves swinging the aircraft from a high structure and then releasing it. The tests show the effects of different types of crash on the human body.

Stone bridges, built hundreds of years ago, are sometimes subjected to heavy pressure from hydraulic pistons so that scientists can assess their ability to withstand vibrations from heavy vehicles.



Structural testing of, for example, bridges, office blocks and oil-rigs, is just as thorough. Wind gusts can affect the comfort of pedestrians near high-rise buildings, or the stability of a helicopter landing on an oil-rig. For this reason a model of the structure is placed in a wind tunnel to assess its behaviour in winds of varying speeds and directions.

Water-tank tests are used on model ships and oil-rigs. Radio-

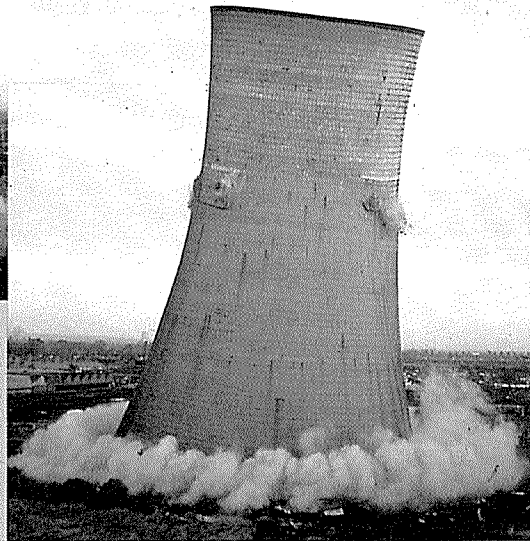
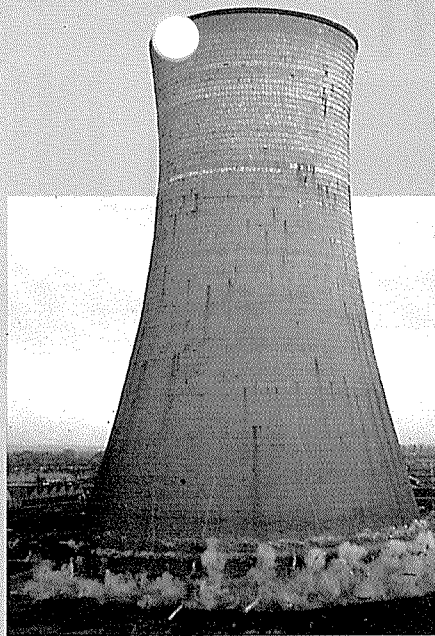


Q DETONATORS

Q NUCLEAR FISSION

Q SEMTEX

EXPLOSIONS



FROM THE VIOLENT eruption of a supernova to the popping of a balloon, all explosions are caused by the abrupt expansion of gas.

Some explosions are caused by combustible materials igniting very rapidly. The burning produces hot gases and also heats surrounding air to produce a fast-expanding blast wave. Coal dust and flour floating in the air can explode in this way. Such materials are described as low-explosive. The resulting shock wave expands faster than sound through the surrounding air, ground or water.



Shockwaves

In other explosives, a chemical reaction creates a shock wave in the material itself that spreads rapidly. A chemical reaction follows closely behind. The material is described as 'detonating'. A great deal of gas is generated very quickly, with shattering effect. A material that normally explodes by detonating rather than by burning is called a high-explosive.

Three stages in the demolition of a water-cooling tower. Holes are drilled in the concrete surface at the base of the towers. Each hole is packed with explosive and connected by wire to an electric exploder sited at a safe distance away.

ICI Explosives



DISASTER IN SIBERIA

Alongside the Trans-Siberia Railway in the Ural Mountains (Soviet Union) runs a pipeline carrying liquid natural gas. On 4 June 1989 the gas revealed its destructive potential. A leak in the pipe had allowed large pools of the liquid gas to gather. Nearby residents noticed the smell that morning. So did passengers on two approaching trains. One was packed with children on holiday. As the trains passed, something – perhaps a spark from their wheels – ignited the gas and created a fireball over a kilometre wide. The colossal heating of the air created a blast equivalent to 10 kt of TNT that knocked the trains off the tracks, and stripped trees of their branches for four km around. Over 600 people are estimated to have died.

Today explosives are of great industrial importance. They are used in mining ore, excavating tunnels, capping oil wells – even to shape metals. In warfare, too, different explosives are used for different tasks.

An important principle in the use of both military and industrial explosives is that the main charge is insensitive (difficult to detonate). The charge is triggered by a small quantity

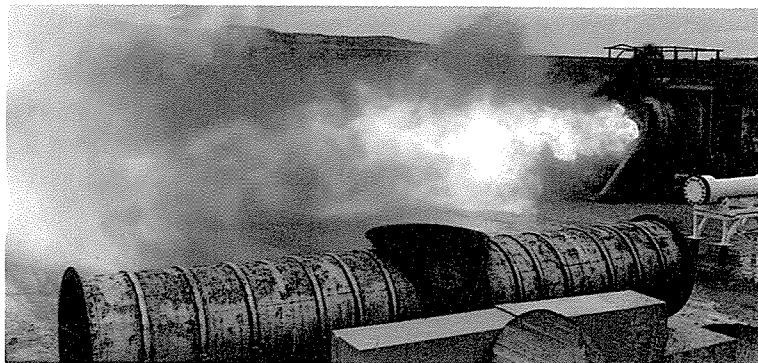
of a substance that is easier to detonate – that in turn may be detonated by a still smaller quantity of a still more sensitive substance.

Plastic explosives

The most widely used industrial explosive – ANFO – consists of small spheres of ammonium nitrate impregnated with fuel oil. Others are gelatinous (jellylike), or powdered.

Plastic explosives are powdered

A simulated coal dust explosion carried out by the Health and Safety Executive, UK. Coal dust is injected into the explosion chamber and ignited by a black powder charge. A blast of this force can be created by 1/2 kg of coal dust per cubic metre.



explosives combined with other substances to make a putty-like material. Because this can be moulded and shaped, it can be readily concealed. Semtex is much favoured by terrorists because of this. It is also relatively hard to detect by dogs, sniffer

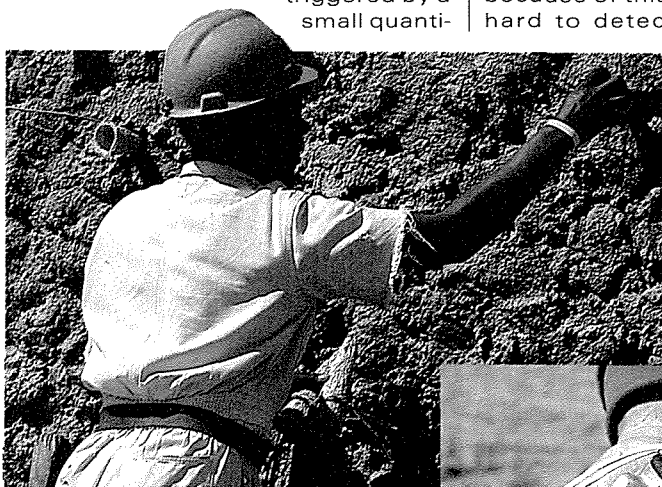
SS-18s, believed to be armed with ten 750-kilotonne multiple independently targetable re-entry vehicles (MIRVs). The US Titan II, with a W-53 warhead rated at 5 to 9 megatonnes, was withdrawn leaving the 1-2 megatonne W-56 the most powerful US weapon.

Krakatoa

The most devastating natural explosion in recorded history occurred on 27 August 1883, when a

large part of the volcanic island Krakatoa, in Indonesia, blew up. Over 36,000 people are estimated to have been drowned by the ensuing 'tsunami' (tidal wave). For months there were spectacular sunsets because of the dust lifted high into the atmosphere by an explosion estimated to have had the equivalent force of a 1,500 megatonne bomb.

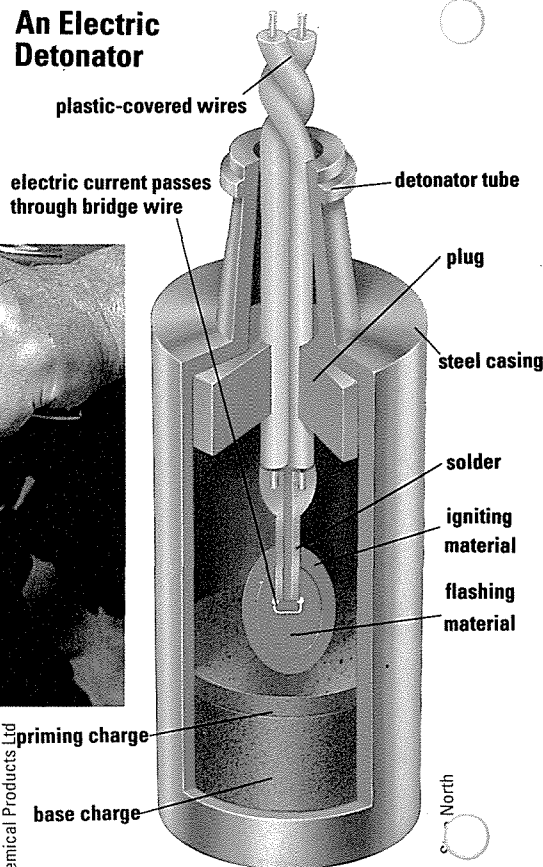
Health & Safety Executive



A gold miner positions a detonator and explosive. Detonation can be effected by heat (fire), by impact or by an electric spark; set off by a hand-held exploder (below).



An Electric Detonator



In electric detonators, an electric current passes through the bridge wire and sets off the surrounding explosive.



Paul Raymond

machines or X-ray detectors.

All chemical military explosives are overshadowed by nuclear weapons. Their strength is expressed in kilotonnes (kt = thousands of tonnes) or megatonnes (mt = millions of tonnes) of TNT. For comparison, Second World War bombs had an explosive power of only a few tonnes of TNT.

The most powerful nuclear weapons ever created are the USSR's

Explosives & Chemical Products Ltd



PAVING THE WAY

Q MACADAM

Q TARMAC

Q ASPHALT

ROADS ARE AN ESSENTIAL part of our lives. They link our towns and cities and we walk or drive over them every day. Yet we take them for granted most of the time and it is only when there are delays caused by road repairs that we realise how important they are.

Although basic roads had been built in China and Asia after the invention of the wheel, it is generally accepted that the first great road-builders were the Roman armies that conquered much of Europe and Asia nearly 2,000 years ago. They were the first road builders to 'camber' the roads. The sides of a Roman road sloped down from the centre so that rain water ran off.

'Macadam'

The great leap forward in road technology came in 18th-century Britain through the two Scottish engineers Thomas Telford and John McAdam. McAdam revolutionized roadbuilding by introducing the system that is still used today.

Roads are made up of a basic layer of stone that has been broken up into different sizes, known as aggregate. McAdam was the first to realize that a combination of small and large stones made the most compact and solid road, because the smaller stones filled in the spaces between the larger stones. This basic material is called 'macadam'.

Roads are a vital means of communication. Their construction is time-consuming and costly, and they must be able to stand even the most hostile environments. They must also be able to withstand heavy urban traffic loads.



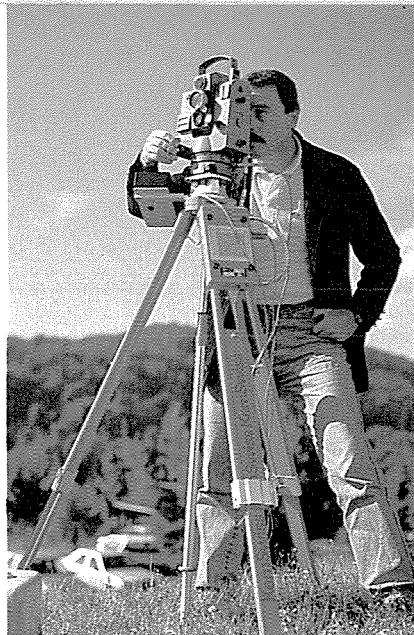
Then it was found that the road could be made even stronger and longer-lasting if the macadam was coated with a binding layer of tar or bitumen. This is now known as tarmac or 'tarmac'.

Smooth and flexible

Today, roads are often surfaced with another material – hot-rolled asphalt, which contains very fine aggregate, such as sand, and a powder known as filler. This is very smooth and flexible too, which makes it ideal for modern road surfaces.

Under the surface of the road,

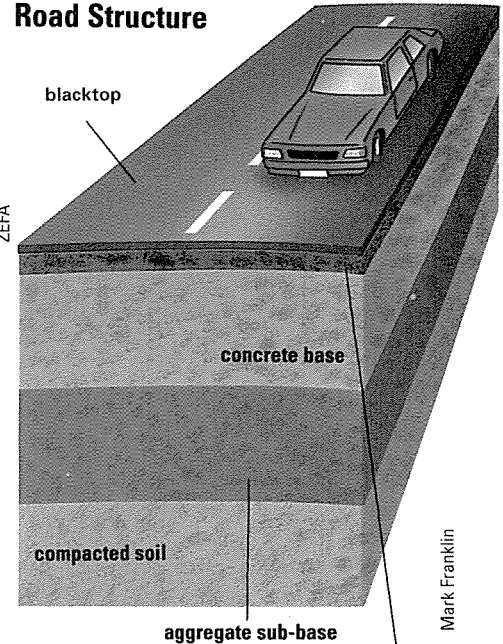
The surveyor must find as level a route as possible that avoids mountains, ravines and existing buildings



smelted. This is known as blast-furnace slag and contains minerals similar to those found in igneous rock. When cooled, it can be crushed in the same way as quarried stone. The ideal shape for aggregate is as near cubic as possible, and it comes in ten grades or sizes from 50mm all the way down to fine dust.

The first step in building a road is

Road Structure



Roads are layered to make them strong, yet able to flex under a heavy load.

rolled black top

Mark Franklin



Tarmac Construction

there are a number of layers of stone. This stone has been blasted by explosives to reduce it to a manageable size, and then broken down even further by secondary blasting or by a drop-ball machine, which breaks up the rock by dropping a heavy weight onto it. It is then taken to a crushing plant, where a huge sieve-like system of parallel bars called a 'grizzly' removes the smaller pieces of stone.

Crushing aggregate

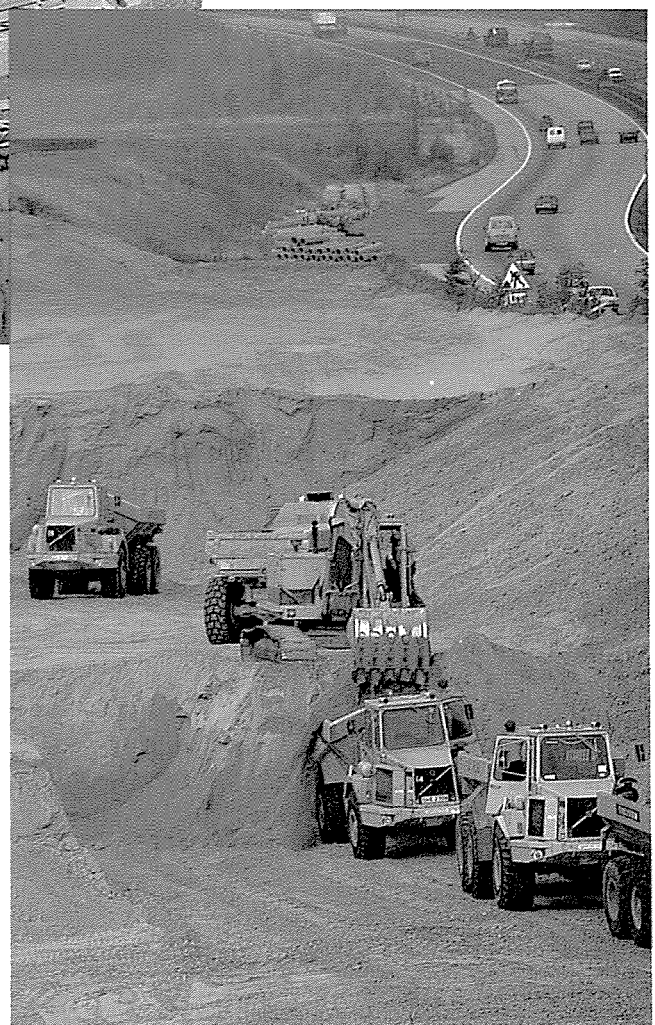
The remaining stone passes through a series of crushers that break it down to smaller and smaller sizes, and it is sorted into different grades of aggregate by passing it over a wire mesh with varying sizes of holes.

There is another important source of aggregate – the non-metallic residue that is left after iron has been

A crushing plant turns rock into aggregate. This is a mixture of stone chips. When laid and compacted by a heavy roller it gives the road a strong base.

The ground itself has to be prepared to give the road a firm foundation.

Heavy 'plant' is used to remove the topsoil. Then the subsoil is levelled, and compacted to carry the weight of the road.



Tony Stone Photo Library London



the planning of its route. This is carried out by surveyors, who take into account geographical features such as hills and rivers, and environmental factors, such as whether the road will cross farmland or an area of housing.

A site is then cleared using enormous earth-moving machinery such as a motor scraper that scoops up earth and carries it away in a large bowl between the axles. Bulldozers are also used for this job. The topsoil is

Road markings have to be added once the road surface has been laid. Reflective paint is used for centre, edge and lane markings so that they pick up the light from vehicles' headlights at night.



Prismo



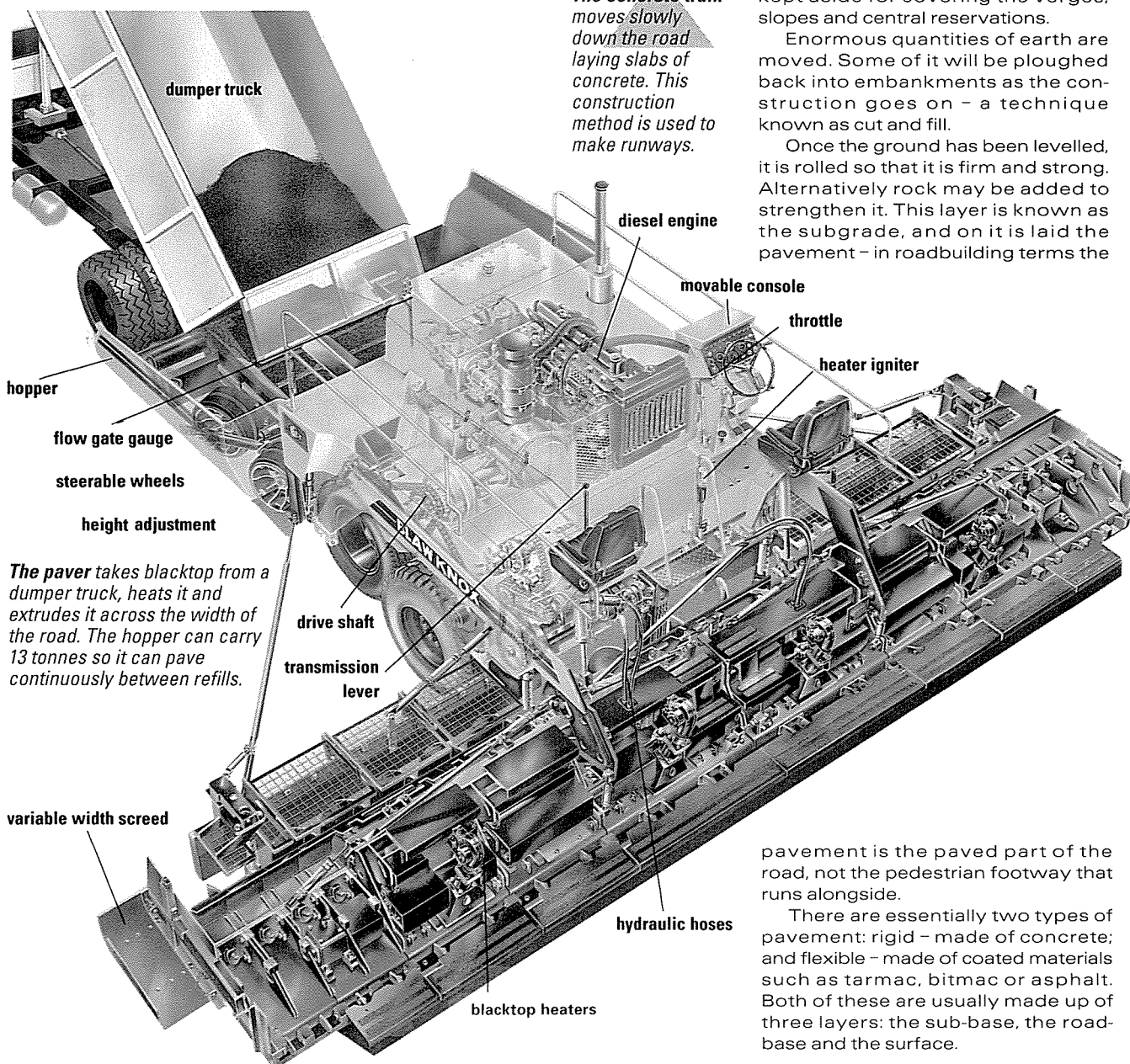
Dr Jeremy Burgess/Science Photo Library

The concrete train moves slowly down the road laying slabs of concrete. This construction method is used to make runways.

kept aside for covering the verges, slopes and central reservations.

Enormous quantities of earth are moved. Some of it will be ploughed back into embankments as the construction goes on – a technique known as cut and fill.

Once the ground has been levelled, it is rolled so that it is firm and strong. Alternatively rock may be added to strengthen it. This layer is known as the subgrade, and on it is laid the pavement – in roadbuilding terms the

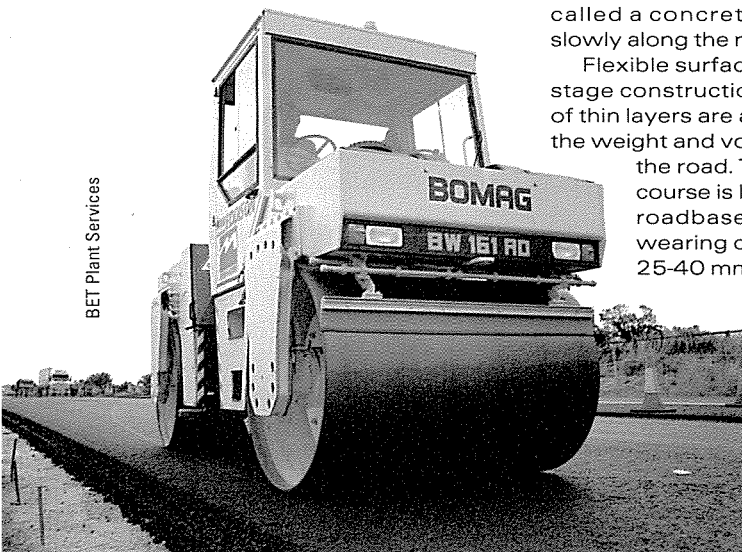


The paver takes blacktop from a dumper truck, heats it and extrudes it across the width of the road. The hopper can carry 13 tonnes so it can pave continuously between refills.

pavement is the paved part of the road, not the pedestrian footway that runs alongside.

There are essentially two types of pavement: rigid – made of concrete; and flexible – made of coated materials such as tarmac, bitmac or asphalt. Both of these are usually made up of three layers: the sub-base, the road-base and the surface.





called a concrete train that travels slowly along the road.

Flexible surfaces can be laid using stage construction, where a number of thin layers are applied according to the weight and volume of traffic using the road. The 45-60-mm base course is laid directly on to the roadbase and is topped by a wearing course that is around 25-40 mm thick.

The flexible surface – known as 'blacktop' – is laid when it is hot by a mechanical finisher. It is then compacted with rollers as the finisher moves along. The rollers may be

CAT'S EYES

The final touch in roadbuilding is to add road markings, such as white lines. These are painted down the middle of the road using reflective paint. For extra safety where there is little or no lighting, reflective 'cat's eyes' are embedded in the surface. These are not cat's eyes at all, but glass or plastic prisms that reflect oncoming car headlights and mark the way. They are also flattened back into the road, so that they do not get damaged or stick out dangerously.

A new surface called Permflex, used on the left carriageway here, incorporates thermoplastic rubber in the bitumen to improve drainage and cut down spray.



Shell

The sub-base is made from crushed and compacted stone or gravel up to 600 mm thick, although in some concrete roads it is left out.

Flexible joints

The roadbase of a rigid pavement is made up of slabs of 'lean cement concrete', often reinforced with steel. This has a low percentage of cement, and the slabs must have flexible joints at regular intervals to allow for expansion caused by hot weather.

In flexible pavements, the roadbase must also be flexible and is made up of layers of coated materials that are laid by a mechanical finisher.

A 'road roller' is no longer driven by steam. Modern 'compactors' have diesel engines. They follow the paver and smooth the finish.

Motorway bridges are made of reinforced concrete and effortlessly span distances unthinkable in other materials.



can vary with temperature. So weather conditions have to be taken into account. Another factor is that bitumen is oil-based and is soluble in oil. So in areas where oil or petrol are likely to be spilled, such as garage forecourts, high-viscosity tar is used.

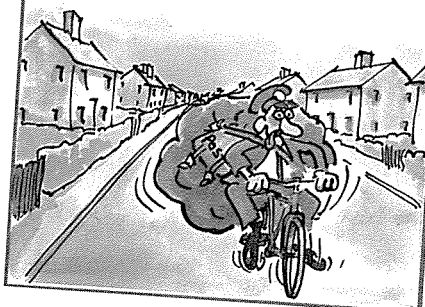
To give extra grip on the wearing surface, a final coating of asphalt with pre-coated chippings rolled into it is applied. This anti-skid surface is used for main roads and motorways.

Just amazing!

STREETS AHEAD

THE WORLD'S LONGEST STREET, YONGE STREET IN CANADA, RUNS 1896.2 KM FROM DOWNTOWN TORONTO TO THE ONTARIO-MINNESOTA BORDER.

Coty/Jerrican



Paul Raymond

It is then compacted using heavy rollers. This type of roadbase is sometimes used under rigid surfaces, making up a composite construction road, often found on airport runways.

The surface of a rigid construction is made up of slabs of concrete up to 250 mm thick. The sections of concrete are called bays, with expansion joints in between that are filled with a flexible and waterproof bituminous compound. The road is laid in a continuous process by a special machine

smooth-wheeled, pneumatic-tyred or vibrating – most are diesel-engined.

Blacktop is usually delivered to the site from an automated plant where the correct amounts of graded aggregate have been weighed by computer, heated and mixed.

The binders

The type of binder used – bitumen, tar or a mixture of both – depends on several factors. One is the stiffness – or viscosity – of the binder, which

THE

BUNGE

Q HYDRAULIC TOOLS

Q THERMIC LANCES

Q RECYCLING WASTE

CONSTRUCTION INDUSTRIES

today are coming to rely heavily on demolition. As land and raw materials become increasingly rare, the

manufacture of tools used in demolition and the recycling of the rubble left behind is now a rapidly expanding industry

Years ago, demolition involved knocking down buildings and dumping the rubble created. Until recently in Britain alone, around 20 million tonnes of demolition rubble was

being dumped annually at a cost of £50 million. At the same time, huge sums of money were being spent on digging up hardcore for use in the foundations of roads and buildings.

Now, much of the waste produced by demolition is recycled. Bricks, which are expensive to buy new, are being cleaned up and rubble is being used again as hardcore.

Conventional demolition equipment – the swinging ball and sledgehammer – was found lacking when faced with modern structures of steel-reinforced concrete.

Peter Menzel/Science Photo Library



Holes for explosives are drilled under expert supervision in precisely planned positions for this potentially dangerous demolition procedure.

Explosive charges have been used to remove key parts of this electric power station, causing the building to collapse under its own weight.



ture of a metal oxide and a reducing agent around the girders or columns of a building that is then ignited electrically. The heat generated by the reaction softens the steel supports which can then be pulled with ropes bringing down the rest of the building.

One of the most effective ways of causing a building to collapse is by using explosives. Charges are laid in carefully chosen points at the

Now a wide range of crushing and cutting machines is available, and demolition techniques have become so advanced that the interiors of fine buildings can be completely gutted without damaging the facades or surrounding areas.

If a building is located in an area

Hydraulic shears can handle tasks from dismantling steel beams to cutting thick metal sheets. Their long reach allows the operator to work at a safe distance.

circular area to be clear when shot-firing begins

20° minimum

chimney

nearest obstructions

arrangement of shotholes for demolishing walls

at least 1.5 x height of chimney
line of fall

A clear line of fall must be established to demolish a chimney safely with explosives. Charges are laid on one side of the base to control the direction of its collapse.

The hydraulic hammer combines an hydraulic drive system and a nitrogen pressure accumulator, making it a powerful and highly versatile demolition tool.



A demolition ball in use. The ball can be dropped vertically on to horizontal surfaces such as floors and roofs, or swung against walls.

well away from surrounding structures, demolition can be carried out by weakening key points of support and forcing the building to collapse.

Thermal reaction

Collapse can be induced in steel structures using the thermal reaction process. This involves packing a mix-



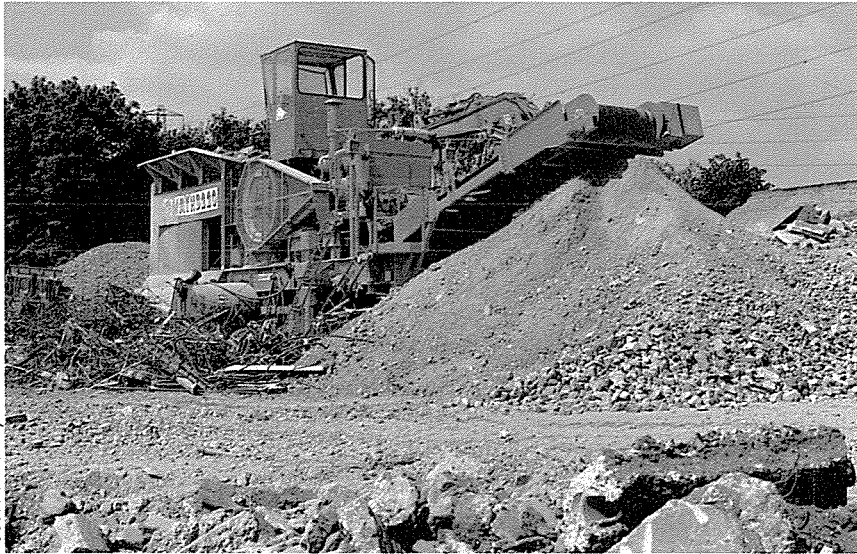
Allied Construction Equipment Ltd

Allied Construction Equipment Ltd

Mark Franklin

Krupp Maschinentechnik





Goodwin Barsby

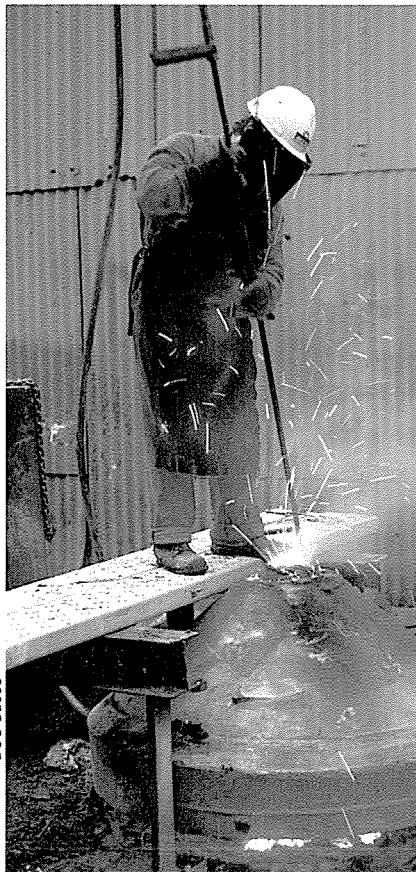
Crushing and cleaning are done at the same time in a crusher, while grid bars in the front section allow undersize material to fall from the feeder.

base of the structure so that when supporting walls are blown away the building collapses.

The tools used for demolition may be hand-held for smaller jobs or attached to motorized vehicles for larger ones. Hydraulic tools can generate enormous pressure with their various attachments.

The first tool used in the demolition process is often a jack-hammer which breaks up or pulverizes concrete. It is

Special clothing and goggles must be worn when using a thermic lance as protection from the hot flame it uses to cut through steel and concrete.



BOC Gases

attached to a flexible, jointed arm that is mounted on a purpose-built tractor-like vehicle. This vehicle has to be sturdy enough to move around on a rubble-strewn demolition site – which usually means that it is fitted with caterpillar tracks instead of wheels.

Another way to demolish concrete is to use a huge pair of me-



Industriebau-Dederichs GmbH

A rubble sorting plant sifts out materials such as brick and stones from the refuse left after demolition so that they can be recycled.

chanized jaws, called a pulverizer, to snap off sections of concrete.

To cut any steel reinforcement, a demolition contractor may use oxy-acetylene torches or hydraulic shears.



Steel and concrete

The shears are mounted on a vehicle for maximum manoeuvrability, whereas torches are hand-held. The torches combine oxygen and acetylene or propane and can cut steel up to 30 cm thick.

Steel and concrete over 30 cm in thickness require the use of an oxygen-powered thermic lance. This is a long steel tube filled with steel rods. The end of the tube is preheated and

oxygen is passed through it, reacting with the steel at the heated end and creating an intensely hot flame that can cut through steel and concrete.

Once the main structure has been reduced to rubble, it is cleared away using motorized scoops and loaders and transported away in lorries.

The emphasis on recycling has led many demolition contractors to install crushing plants which reduce rubble

TRICKY SITUATIONS

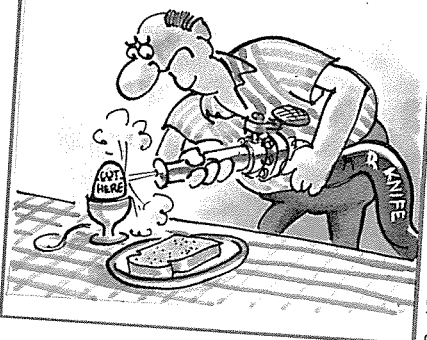
For delicate excavation work on a site where pipes or cables in the ground may be cut by digging equipment, a high-velocity compressed air hose can be used to blow away or extract soil without any risk to the pipes, cables or operator. The opposite effect is obtained with an excavator, which uses high-velocity compressed air to create a vacuum, picking up water, soil and rocks up to 10 cm in diameter.

to workable-sized pieces for hardcore. Materials such as wood and brick are also salvaged and can be separated by running them through a tank of water in which the wood floats and the brick sinks.

Just amazing!

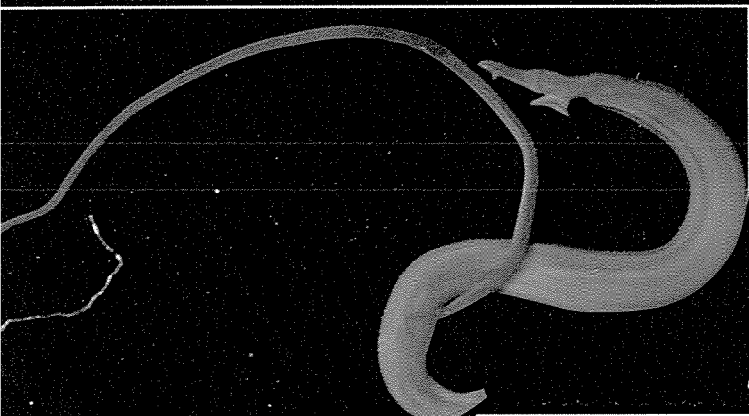
THE TENDER TOUCH

THE AIRKNIFE – A COMPUTER-CONTROLLED EXCAVATION TOOL – USES AN AIRSTREAM THAT BLASTS AWAY SOIL BUT IS SO SENSITIVE THAT ITS MAKERS CLAIM IT WILL NOT CRACK AN EGG.



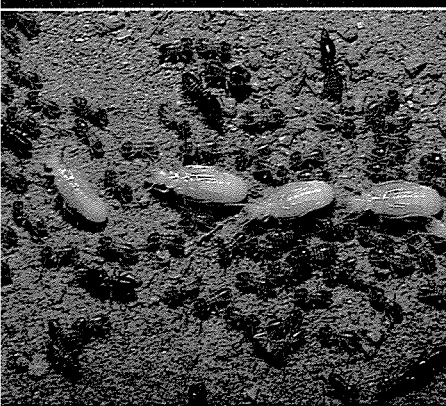
Paul Raymond



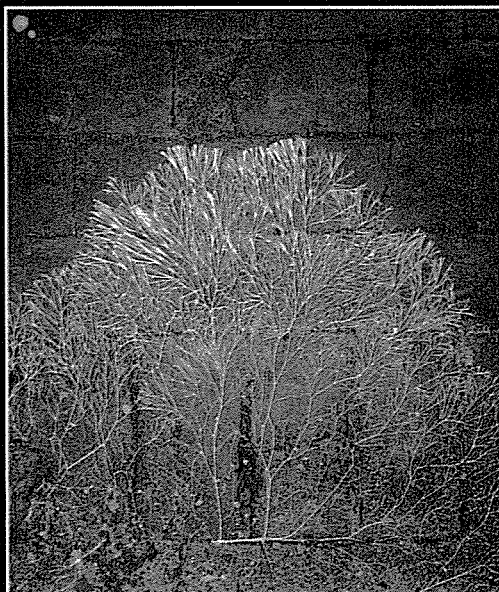


Tiny blood flukes are carriers of bilharziasis. Infectious to Man, they pierce the skin and travel through the bloodstream to mature and mate in the liver.

Termites – ant-like insects – may survive exclusively on wood and flourish in the tropics. A colony of a million or more on a feeding march destroys acres of trees.



London Scientific Films/Oxford Scientific Films



Dry rot fungi play a vital role in woodlands of breaking down aged trees. When attacking the timber of buildings it can cause major structural damage.

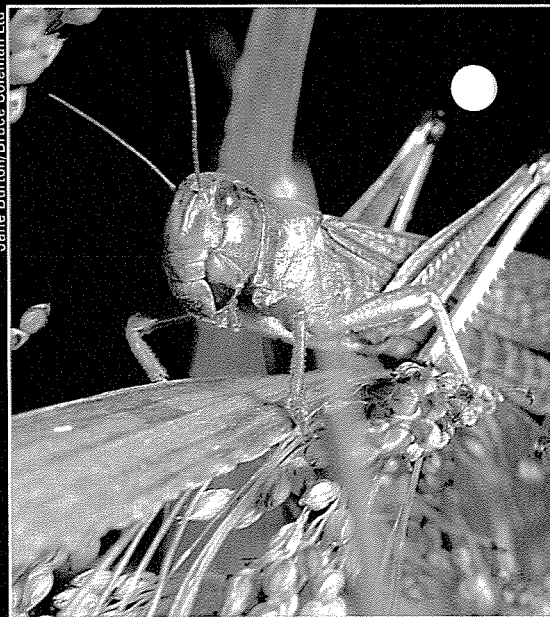
Kim Taylor/Bruce Coleman Ltd



A furniture beetle emerges from infected wood. 'Woodworm holes' are the exit tunnels of beetles that have matured from woodworms living in the wood.

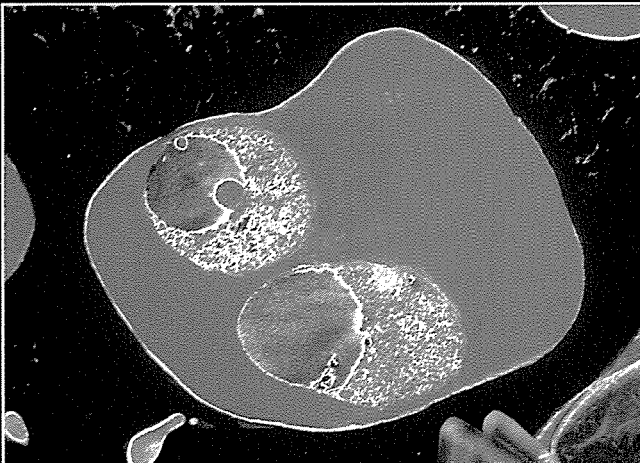
Cair Ellis/SPL

Jane Burton/Bruce Coleman Ltd



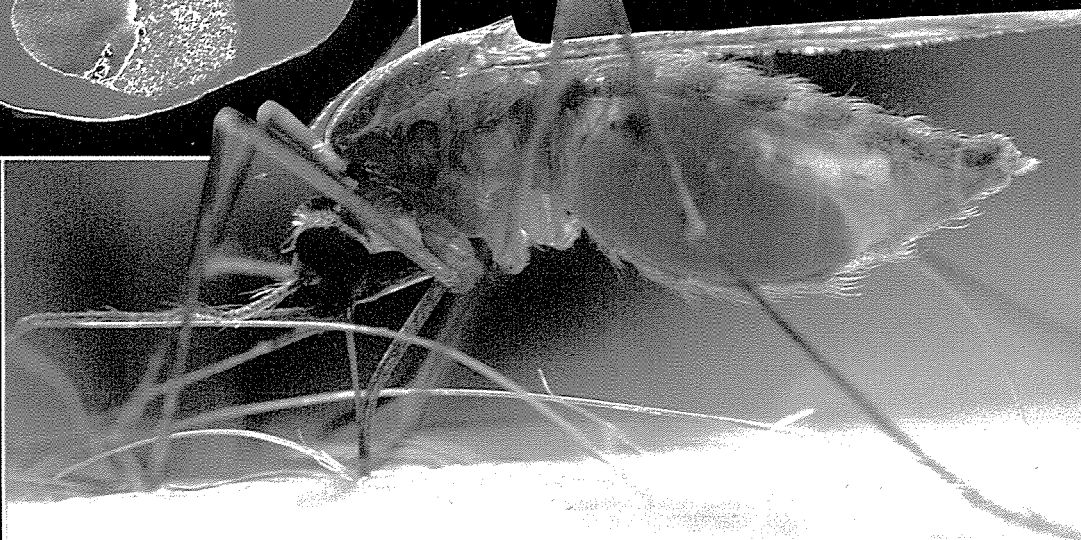
Locusts in modest numbers do little damage to vegetation, but a swarm will devour all in its path.

Richard Packwood/Oxford Scientific Films



Infected mosquitoes deposit malaria parasites as they suck blood from a host. The parasites release merozoites that enter red blood cells and the victim contracts malaria.

CNR/Science Photo Library



London Scientific Films/Oxford Scientific Films

Q MOBILE CRANES

Q COUNTERBALANCE

Q TELESCOPIC ARMS

Jib cranes for operators with a head for heights, at Canary Wharf, London, UK. Their lifting capacity and wide reach make them extremely useful on construction sites.

GIANT HANDS



CRANES ARE ESSENTIAL IN THE construction industry. Without them, many huge modern structures would not be possible. No better method of lifting heavy loads has been found.

There are many different types of crane and the model used is selected according to the purpose for which it is required and the size of the load to be lifted. Some are stationary, while others are mobile and may be transported from site to site. They are usually made of heavy-duty tubular steel, sometimes octagonal in cross-section for extra strength.

Pulley system

All cranes operate in the same basic way using the principle of pulley systems to lift loads. Their lifting apparatus is attached to steel cables, or chains that pass through pulley

systems and are wound on a drum, known as the hoist. The ability to lift and displace loads horizontally as well as vertically is the distinguishing feature between cranes and other simple lifting devices.

Bridge cranes

The two main types of crane are bridge – or portal – cranes and jib cranes. Within these divisions there are numerous varieties. Bridge cranes include overhead travelling cranes and Goliath cranes. Among the types of jib crane are tower cranes; telescoping boom cranes; scotch derrick cranes and level luffing cranes.

A bridge crane has a trolley or cab that travels along the overhead bridge and carries the lifting mechanism. The horizontal bridge is supported on legs

Independent wheel suspension is one of the innovations in crane manufacture that increases manoeuvrability of mobile cranes on difficult terrains.

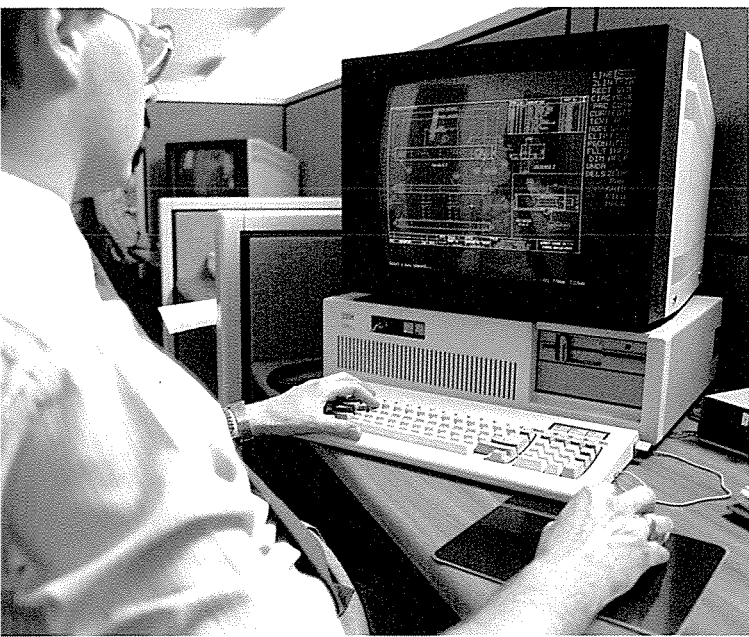
– in cases where the legs are equipped with wheels which run on parallel rails or tracks, the cranes are known as Goliath cranes.

Overhead cranes

The most commonly used bridge crane is the overhead travelling crane found in factories, power stations and areas where floor space is restricted. The hoisting apparatus travels back and forth across the width of the working area on an overhead bridge made of steel girders. The bridge itself

Krupp Industrietechnik





Computer analysis is applied to various aspects of crane manufacture. In the case of box beams for overhead cranes, this has resulted in improved welding techniques to give higher rigidity and less load bounce.

mobile. They can be assembled quickly on site in sections to make what are known as tower or cantilever cranes, that resemble a giant 'T' shape. These are the cranes that are visible in urban skylines rising 100 metres or more over major construction sites.

Cantilever cranes consist of a tall vertical latticework tower with a main jib extending out at 90° to the tower, and a smaller, shorter jib extending in the opposite direction holding a

A mobile crane in the process of assembly with the use of an overhead crane to lift and position the crane operator's cab.



Street Crane can travel the length of the building on trolley wheels along an elevated framework (gantry), which supports it at each end. The gantry is built against the walls of the room, or alternatively is a structural part of the building's framework. Thus the crane can pick up a load and put it down anywhere in the room without taking up any floor space itself.

Overhead travelling cranes maximize restricted space. Over-hang rotating trolleys can cover the entire floor area.



Aumund GmbH

The positioning of the hook or winch can be automatically programmed or manipulated by an operator, either directly or by remote control. Remote control operation using television cameras is especially important in areas hazardous to humans. This means that the operator does not have to be positioned near the crane or its load; he or she has, therefore, greater flexibility.



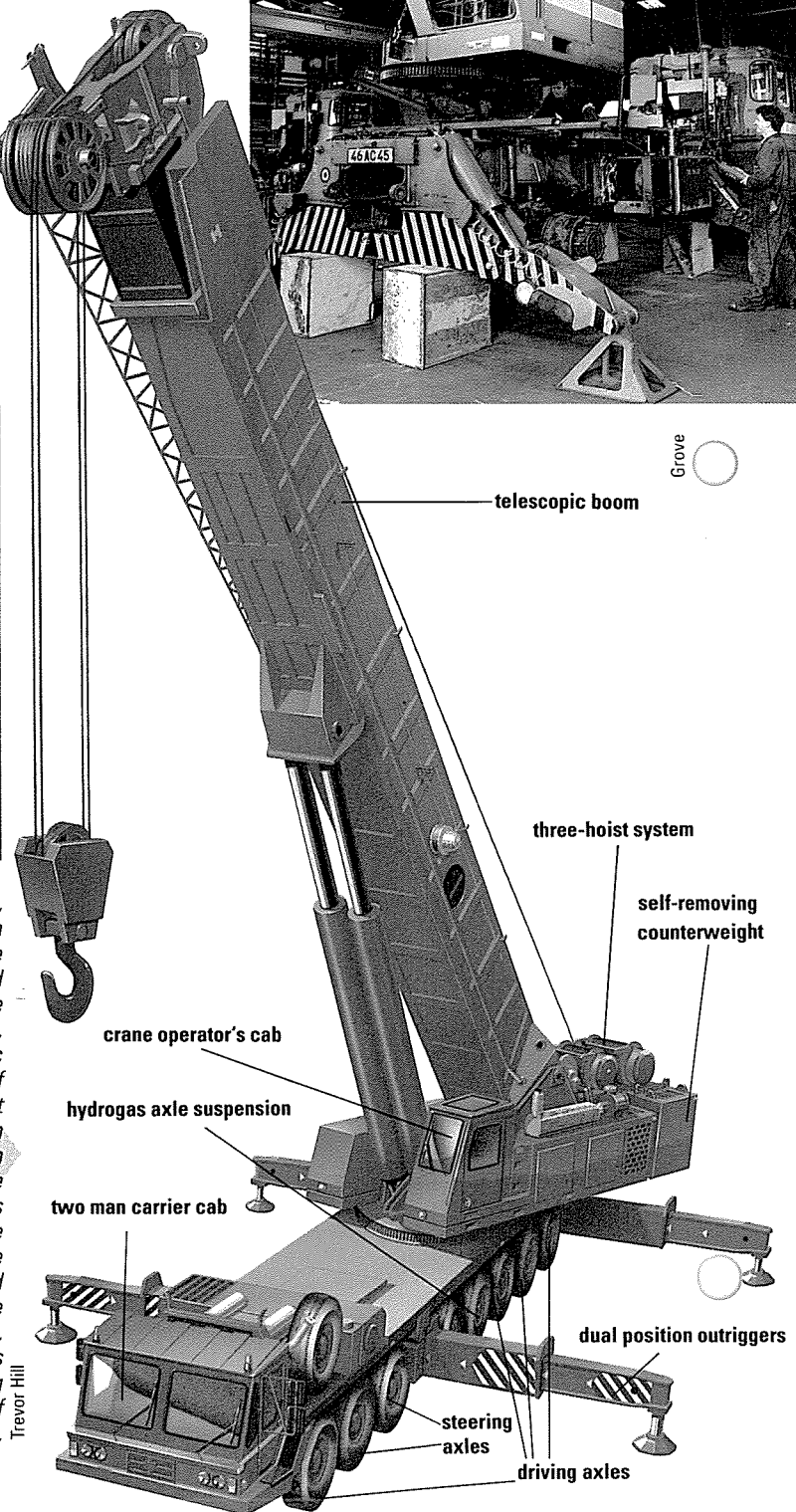
Jib cranes

The other major group of cranes – jib cranes – is used mainly in construction. These have an arm, the jib or boom, that can move up or down and rotate about a central point, an action called slewing. This gives them great manoeuvrability and makes them especially useful in confined areas.

Jib cranes are also generally

A telescopic crane, the TM2500, is a massive 16-wheeled juggernaut capable of lifting 225 tonnes.

The telescopic boom consists of five sections that can extend from 14 m to 53 m in ten minutes. The crane operator has joystick remote controls for crane functions and switches for the telescopic boom. Pressure switches activate warning systems in case of overload.



Grove

Trevor Hill





heavy counterweight. Sometimes the counterweight is in the base of the tower attached to the jib with cables. The lifting cables are attached to a trolley that travels along the main jib, and are operated by the turning of a huge motorized drum. These cranes can lift up to 150 tonnes.

Lifting capacity

For greater mobility and flexibility, self-propelled cranes can be driven directly from job to job on caterpillar tracks. Usually smaller than tower cranes, they are more versatile and can lift much heavier loads, some-

A telescopic crane at work on a demolition site. To minimize the risk of overturning, counterweights are an essential part of a truck-mounted crane's operating equipment. These are visible positioned at an angle of 180° to the jib, where they offer the greatest leverage.



times up to 1,000 tonnes.

Some cranes are mounted on the back of huge trucks, which have extension arms to help stabilize the crane when in use. These trucks may have eight axles and sixteen wheels or more, because of the weight needed to keep the crane stable.

Counterweights

One of the major problems associated with jib cranes is that they have to counterbalance the huge weights they lift. Because they are not supported by columns either side of

lifting gear, as bridge cranes are, they need to be balanced by enormous weights (usually blocks of concrete) to prevent them from toppling over when lifting heavy loads.

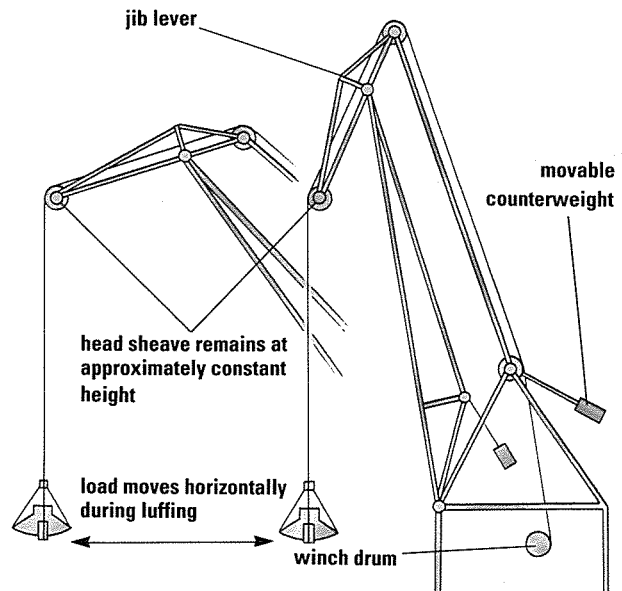
Tower cranes have heavy steel or concrete counterweights set out opposite the lifting arm. Road cranes have the same sort of counterweights mounted in the base or substructure, often with cables running up and over the jib to act as a cantilever. Cantilevering arrangements can be quite complicated, with several sets of support cables working together.

The stability of the crane is measured in terms of its safety against overturning. This is carefully calculated so that the crane is not overloaded and in danger of toppling.

Safety equation

This 'overturning moment' is worked out by multiplying the weight of the load by its radius – the radius is the distance from the load to the king pin of the support tower. The radius in turn differs according to the slope of the jib, so that when the jib is raised steeply, the radius is small and the crane can carry a heavier load than with a larger radius.

THE HEAVY LOADER



Mark Franklin

Loading cranes moving freight containers at Felixstowe docks, England. Major ports utilize quayside cranes mounted on rails that run parallel to the quay, thus allowing them to be moved alongside any berth. Lifting capacity can reach 40 to 50 tonnes.

The upwards and downwards movement of a jib arm is known as derricking or luffing. But for some specialized operations such as loading and unloading from ships at ports, a level-luffing crane is necessary. In this type of crane, the load moves in a horizontal path as the jib is raised or lowered. This is achieved by using an extra section at the end of the jib called a jib lever that acts to compensate the luffing movement. As the jib swings up, the lever tilts down by using movable counterweights to keep the load at the same height. An added advantage is that the projecting lever gives extra clearance from the main arm when handling bulky loads.

The calculation of the maximum radius multiplied by the weight of the load gives the crane its maximum lifting capacity. This maximum must never be exceeded.

Attachments

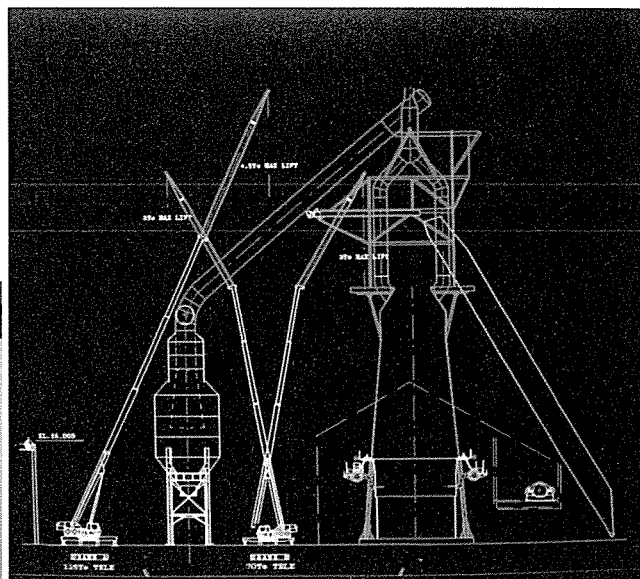
Cranes do more than just lift; they can use a variety of attachments for specific jobs. The most common attachment is the hook for lifting, but cranes can also have grabs, buckets



The grab is used for lifting quantities of loose material such as soil or coal. Its two shell jaws open and close by operating a holding and a closing cable in turn.

To give cranes extra height and manoeuvrability, they can have extending telescopic arms or articulated arms with several joints allowing

Computer simulation of a crane lift. The objective is to find the most efficient way to move a load and test the feasibility of proposed equipment.



BET Plant Services



Street Crane

Aumund GmbH

them to move in several ways. A telescopic jib crane will drive to a site with its jib retracted and flat. Once in position, and with the stabilizing arms set out, the main jib is lifted by hydraulic rams attached to a fly jib beneath it.



Weight distribution

Once at the required angle, the jib can extend out to its full length and the lifting can begin. The lifting gear consists of heavy-duty steel cable wound round motorized drums, with a system of pulleys to spread the load—driven across the whole cable, thus reducing the strain on any one point.

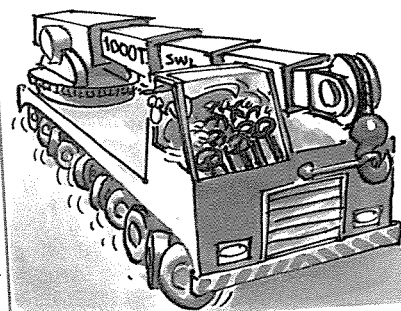
Nearly all jib cranes are operated from a cab; for a tower crane the cab is usually at the top of the tower but

Remote-controlled operation of lifting and placing loads enables precise positioning to the nearest millimetre – especially useful in work areas that are hazardous to humans and in areas where sterile conditions are required. Hand-held remote-control systems (right), allow the optimum position for viewing the load.

Just amazing!

POWER STEERING

THE WORLD'S LARGEST TELESCOPIC TRUCK CRANE, WITH A LIFTING CAPACITY OF 1,000 TONNES AND A SPEED OF 72 KM/H, HAS TEN AXLES — NINE OF WHICH ARE STEERED.



Paul Raymonde

for mobile cranes the cab is usually close to the ground, situated on the substructure. Where the cab is at a high level, there are strict limitations as to the weight of the load lifted. This safety limitation is often controlled by 'safeload' indicators inside the cab. The operator has an array of buttons and levers to move all the various parts, usually by hydraulic action, although servo motors and electric drives are used as well.

Operating a crane is a skilled and potentially dangerous business, so the drivers have to be well-trained

and safety-conscious. A trainee spends six months with a trained operator and must attend courses.



Automatic cut-out

As cranes carry heavier loads, so increasingly sophisticated manufacturing technology is employed in their design, producing such safety innovations as an 'overload cut-out'. This electro-mechanical load cell is built into the hoist diverter assembly so that if an operator attempts to lift more than the safe working load the motors that drive the hoists cut out.

OFFSHORE LOADING

LASH VESSELS

TRANSPONDERS

PORTS OF CALL

The port of Singapore is the busiest in Southeast Asia. As a free port, there is no payment of import duty on goods being unloaded and reshipped.

ADVANCES IN THE WAY cargo is carried by sea have revolutionized ports and harbours. New methods of handling goods and provisions for very large ships are among the most obvious changes.

Over the last 40 years, the number of passengers travelling by sea has fallen dramatically due to competition from jetliners. Yet ships still reign supreme for transporting bulky or heavy cargoes between continents. In the past, dockyards employed large numbers of people for loading and unloading. Goods were generally

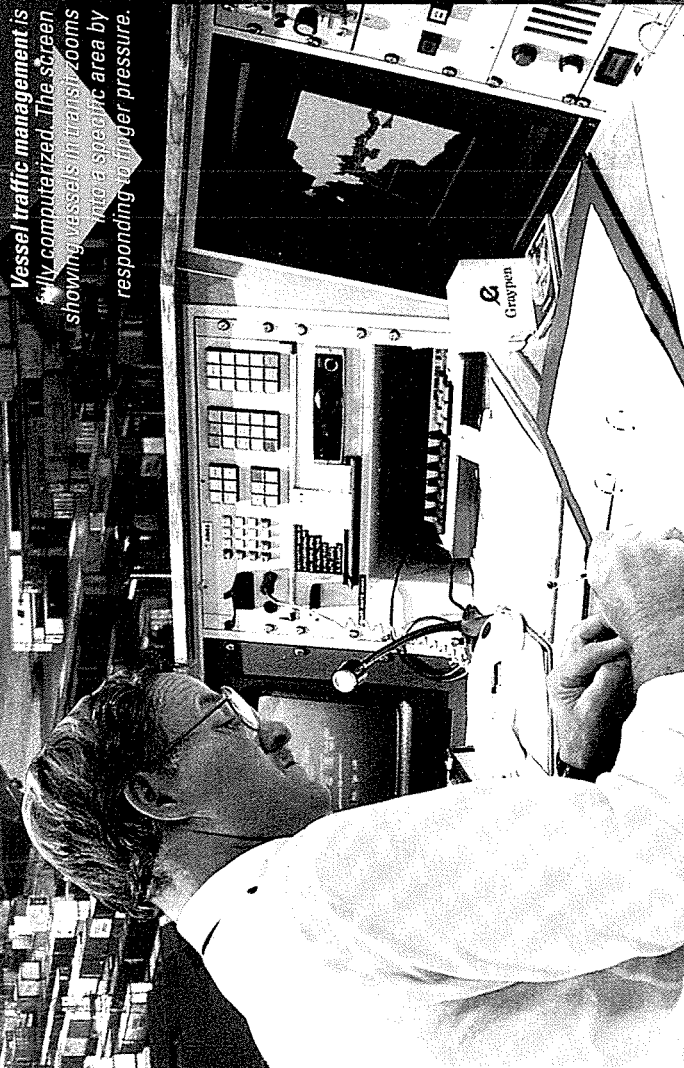
packed in small crates or sacks and either carried down gangways or slung from simple cranes to nets or baskets. It could take 25 dock workers a week to load or unload a large vessel carrying a loose cargo like this.

Container handling

Today, many items are pre-packed for shipping in large, standard-size metal containers at a factory. These are delivered to the port by lorry or train, then lifted off by a special crane known as a straddle carrier.

Each container is put on a marked space on the dockside. A giant

Vessel traffic management is fully computerized. The screen showing vessels in transit zooms into a specific area by responding to finger pressure.



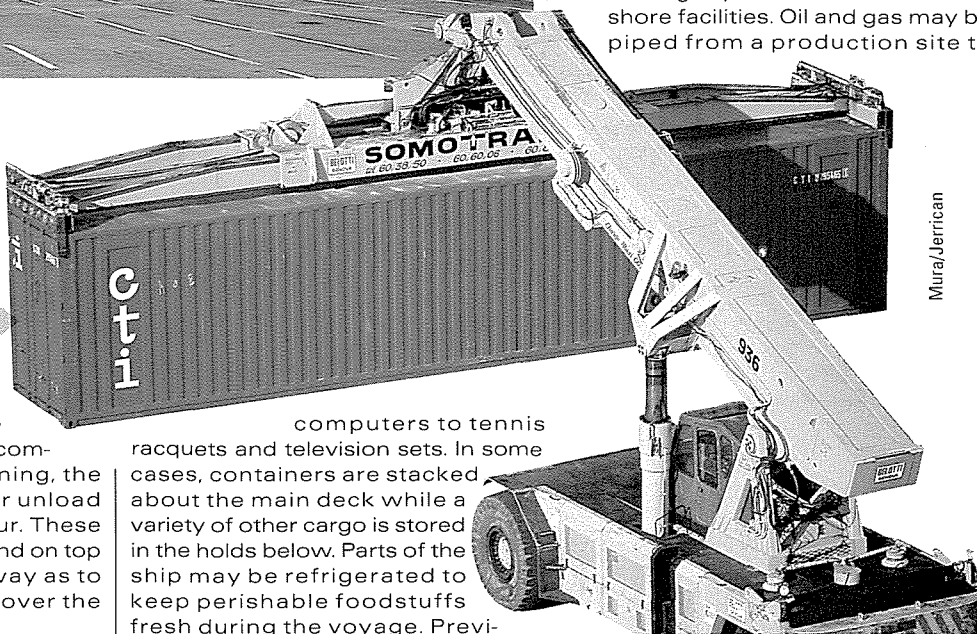
Sperry Marine





A giant gantry crane for lifting containers dominates the quayside in Singapore. Ships en route to Japan, China and Australia unload and load here.

A standard container being transported by a forklift truck at Marseille, France. Once unloaded, goods are moved to adjacent road or rail terminals.



Mura/Jerrican

gantry crane then loads the containers aboard. Using a computer for accurate positioning, the crane operator can load or unload about 30 containers an hour. These are stacked close together and on top of one another in such a way as to spread the weight evenly over the whole of the ship's hold.

The largest container ships can carry up to 4,000 containers, holding everything from clothing and

computers to tennis racquets and television sets. In some cases, containers are stacked about the main deck while a variety of other cargo is stored in the holds below. Parts of the ship may be refrigerated to keep perishable foodstuffs fresh during the voyage. Previously, goods such as bananas were packed unripe in crates so that they would ripen en route, although many simply went bad.

Other types of cargo are now also handled in a much more efficient way. Oil, for instance, instead of being loaded and unloaded in barrels, is simply

pumped into and out of the huge tanks of a supertanker. Similarly, grain is carried loose and unloaded at great speed by powerful suction tubes rather than being hoisted out tediously in sacks by a crane.

Supertankers

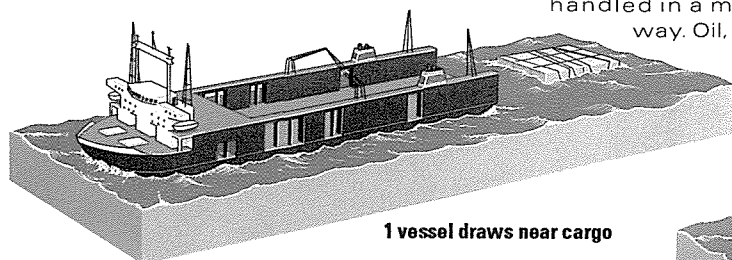
The size of vessels carrying bulk cargoes, such as oil, liquefied natural gas, ore, and grain has also increased tremendously. Currently, the largest ship capable of carrying dry cargo is the Norwegian ore carrier *Berge Stahl*, with a deadweight of 364,767 tonnes and a length of 343 metres. Supertankers can be even larger – up to half a million tonnes. Such enormous ships require special deep water channels and unusually long berths to be able to dock.

An alternative way of loading and unloading supertankers is to use off-shore facilities. Oil and gas may be piped from a production site to

massive underwater storage tanks. The supertanker moors to a floating buoy located in the sea directly above the storage tank and has oil pumped aboard through flexible pipes. In other cases, the oil is pumped directly to the buoy from the production site and then straight on to the ship.

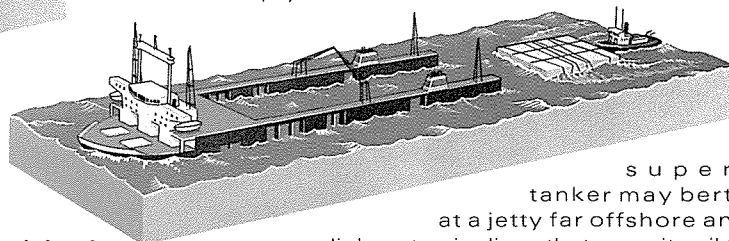
To unload at its destination, the

Loading Sequence

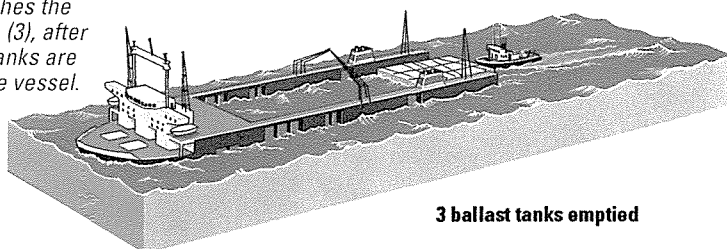


1 vessel draws near cargo

A LASH (Lighter Aboard Ship) vessel. To load lighters, the lighter is positioned behind the ship (1). The LASH vessel is lowered by flooding the ballast tanks (2). A tug pushes the lighter into position (3), after which the ballast tanks are emptied to raise the vessel.



2 cargo floated aboard



3 ballast tanks emptied

super-tanker may berth at a jetty far offshore and link up to pipelines that carry its oil to storage tanks on land. From these, the crude oil is piped to a refinery.

Lighters

Another way of getting cargo to smaller ports is by a type of vessel called a LASH, or Lighter Aboard Ship. Barges, or lighters, are loaded up at a shallow-water port, often inland, and then towed to a deep-water port.

There, the LASH takes the lighters on board by partly flooding its hull. At the next port, the lighters float off again, carrying their cargo by river or canal to its final destination.



Ro-Ro Ferries

Passenger terminals, linked to high-speed roads and railways, are now able to handle huge volumes of car, coach, lorry, and rail traffic. Many ferries are of the Roll-on Roll-off (Ro-Ro) type, so that vehicles can be driven on and off them without delay. Hinged doors at the bow are swung open and steel ramps lowered to give

Foto Flite

The Atlantic Forest – a LASH vessel – can carry 83 loaded lighters, each of which can accommodate 380 tonnes of cargo. In a port such as Rotterdam, the lighters can sail directly to upriver ports and inland waterway destinations.



Gamma/Frank Spooner Pictures

A Heavy Lifter vessel for transporting bulky and awkward packages. The top of the bulwark is designed to be the same height as the top of the hatch covers so that lengthy pieces of cargo can be stowed across the deck.

Ships entering port from foreign countries are checked thoroughly to make sure they are not carrying illegal immigrants, goods or dangerous diseases. Customs officers board a vessel before it docks to see that no one on board is ill, or lacking proper authorization and to search for smuggled goods, such as drugs or weapons. After docking, the cargo is unloaded and may be inspected again. Above, the US Seventh Coast Guard, whose headquarters are in Florida, conduct a search operation. The huge area covered by these guards interfaces with 24 foreign countries and the majority of law enforcement cases conducted in district waters involves the interception of drug smugglers.

Other responsibilities of the coastguards are to ensure the safety of vessels, to protect waterfront facilities from damage, to monitor pollution incidents and enforce pollution laws.

easy access to parking spaces in the hold. Then, when the ferry reaches its destination, the stern of the ship hinges back to let the vehicles drive out in the direction they are facing. A reappraisal of this design of craft was begun after the ferry *Estonia* sank in the Baltic Sea in 1994 with great loss of life.

No captain can know the details of every port or harbour, so usually a pilot comes out to a large ship to help steer it in safely. The pilot has a detailed local knowledge of the port and its waters, including the exact position of deep water channels.

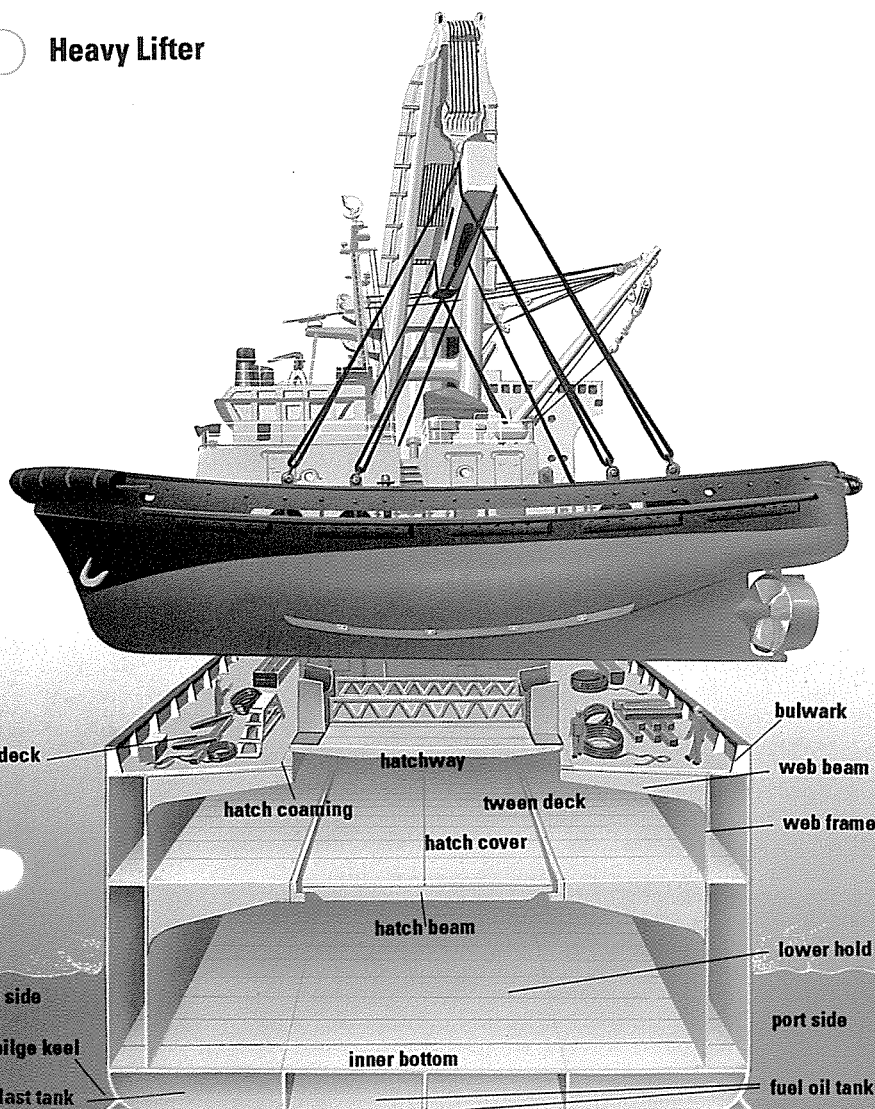


Automatic guidance

More and more major ports are being equipped with automatic guidance systems for ships. Two rows of bleeping transponders moored to the seabed mark the sides of the channel that the vessel must follow. Other transponders, fixed to the ship's keel, pick up these signals and use them to control thrusters under the stern and bow. By this means, the ship steers itself into port automatically down the proper course or 'fairway'.

Large vessels are difficult to stop and manoeuvre in confined spaces.

Heavy Lifter



Trevor Hill





Robert Harding Picture Library

For this reason, tugs are used for the final stages of bringing them in and out of port.

Though small, tugs have extremely powerful engines. The most powerful, the *Volradd Waltemade* and her sister ship *John Ross*, are 94 metres in length and rated at 19,200 shaft horse-power. As well as towing

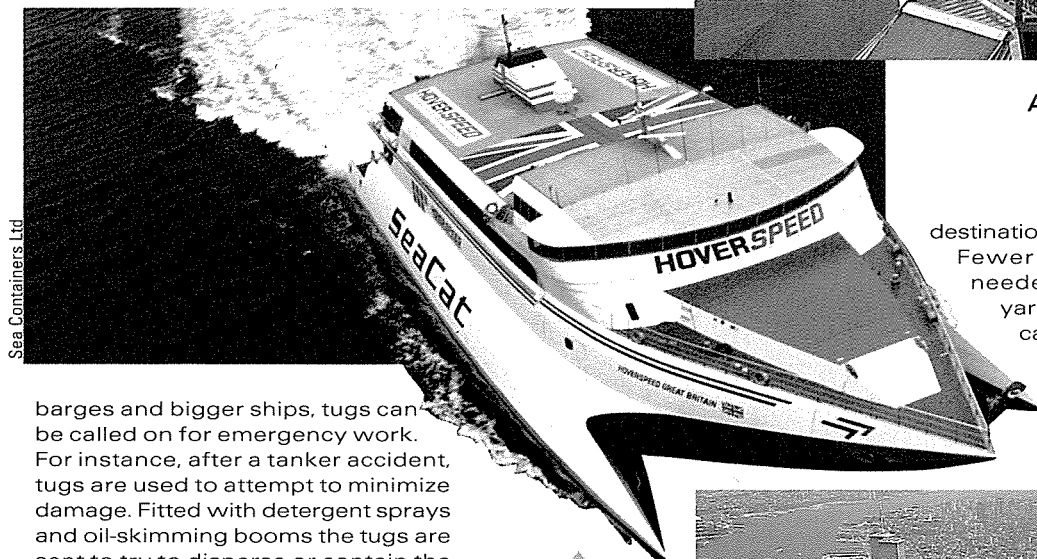
Los Angeles is the busiest port on the west coast of the USA. It covers about 3,000 hectares making it one of the largest artificial harbours in the world.



Rex Features Ltd

A Ro-Ro (Roll-on, Roll-off) ferry being boarded by motorists at Dover docks – the busiest passenger port in the UK.

destination faster than ever before. Fewer and fewer people will be needed to man ships and dock-yard equipment. Already, large cargo ships can be run by just five or six people. A similar number can unload a container ship in a day or less. Eventually, there may be robot



Sea Containers Ltd

barges and bigger ships, tugs can be called on for emergency work. For instance, after a tanker accident, tugs are used to attempt to minimize damage. Fitted with detergent sprays and oil-skimming booms the tugs are sent to try to disperse or contain the

The world's largest catamaran (74 metres long) is designed to cut through waves of up to four metres rather than ride over them.

New York harbour is one of the world's great natural harbours, its deep water being almost surrounded by land.



Robert Harding Picture Library

spill before it reaches the coast.

Large modern ports, such as Rotterdam, New York, and London are being increasingly well linked with inland cities by road and rail services. This, together with more efficient loading and unloading of cargoes, means that freight can reach its

tankers and other cargo vessels, guided by orbiting satellites and navigation beacons on sea and land. Automatic berthing systems will allow these uncrewed ships to dock without human assistance and even be unloaded by computer controlled cranes.



Paul Raymond

SHIP SHAPE

THE BIGGEST OIL TANKERS are as high as a 20-storey building and can hold over half a million tonnes of crude – enough to run 14 million cars. They are so long that crew members ride bicycles to travel from bow to stern. Building such monsters requires special methods and super-scale facilities.

As with all ships, a supertanker begins life as a specification and a design. The specification, supplied by the shipowner, includes details of the cargo to be carried, together with the vessel's proposed speed and operat-

ing range. It is then the task of a naval architect to come up with a design to match these requirements. For instance, the amount of cargo that the owner wants carried determines the size of the cargo holds. The weight of cargo and the specified speed decide what the engine power should be.

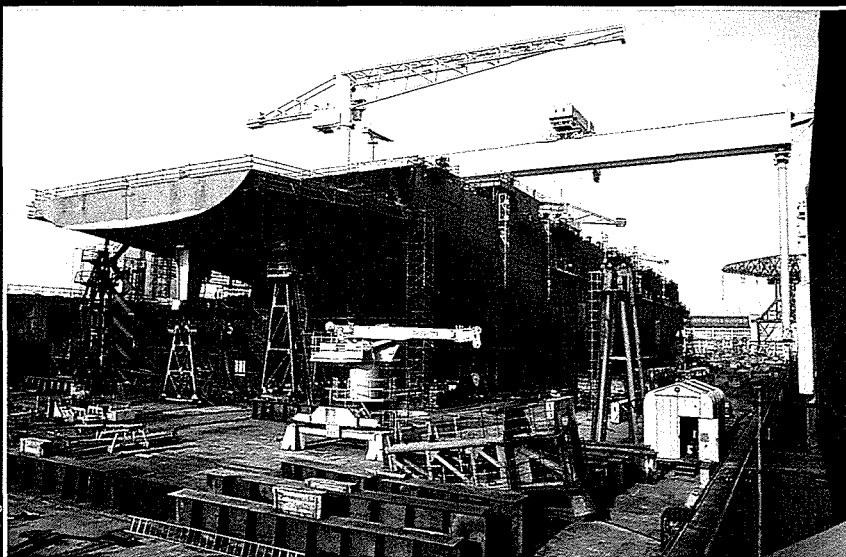
Hydrodynamic tests

The naval architect builds up a complete 3-D picture of a proposed new ship in a computer's memory, then subjects it to a battery of simulated structural and hydrodynamic tests. When the design is complete, it is presented in a report to the shipowner.

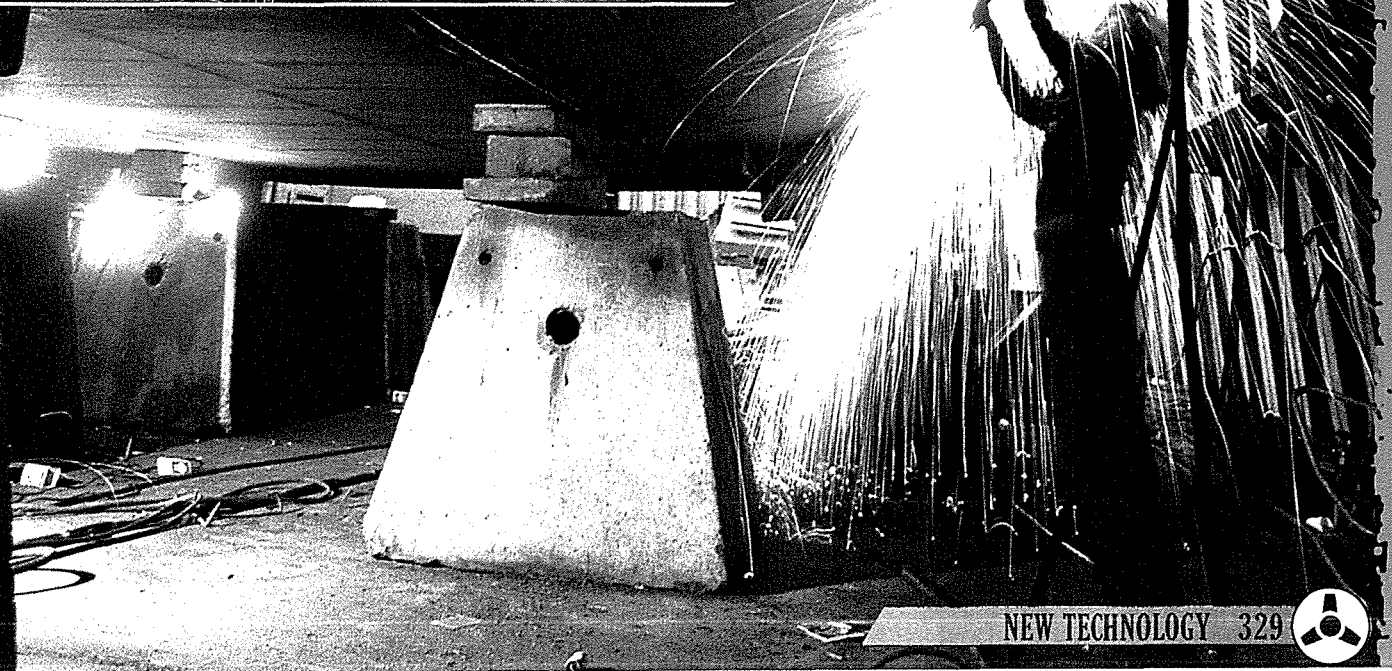
Metal-hulled ships are made by cutting sheets of metal, bending them in a huge press and riveting or welding them together to make a joint that is watertight.

Huge cranes are used to move parts of the ship into place. The bridge, the engine and sometimes whole sections of the ship are made separately and swung into position.

Berenguer/Jerrican



Robert Harding Picture Library



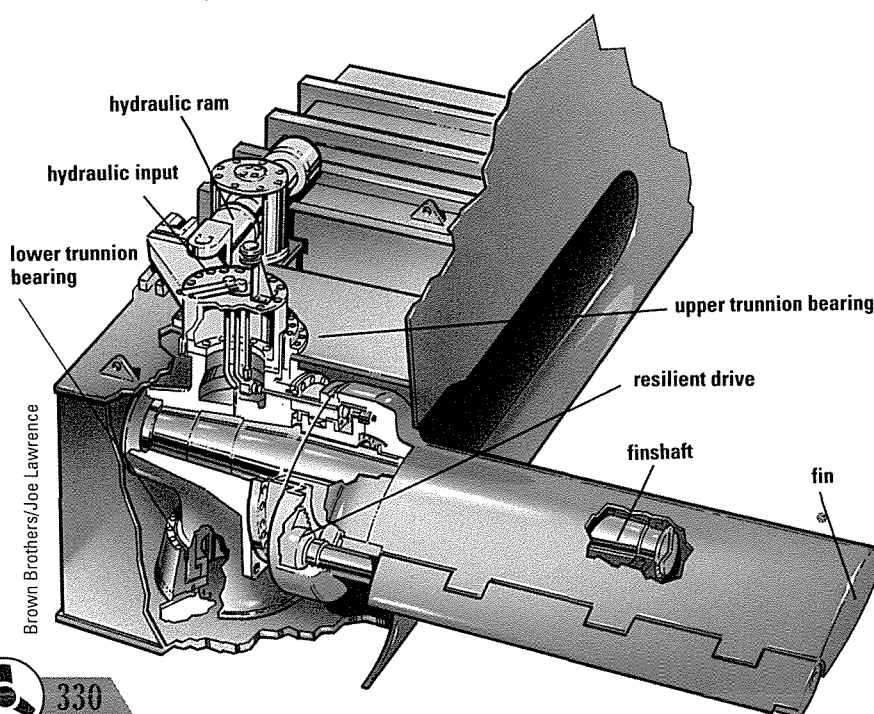


If the owner agrees with the plans, the next stage is to build a scale model, usually from wax, for testing in a large water tank. The testing-tank has a travelling arm above it that can be moved at various speeds while

SUPERTANKERS

The largest supertanker afloat is the *Jahre Viking* with a deadweight of 564,650 tonnes, 459 metres long and 69 metres across. A ship of this size is extremely difficult to manoeuvre. When travelling at speed, for instance, a supertanker needs several kilometres of searoom in which to stop and typically has a one km turning circle. For this reason, onboard computers are used to maintain the ship's course and control most of its movements.

A stabilizer fin counteracts the roll of a ship. It is tilted about the finshaft by a resilient drive. This unit is mounted on trunnions and retracted by a hydraulic ram.



Painting the hull is done with a remote painting arm at the Yokohama Works in Japan. The inside of a ship is decorated, or renovated (above) when the ship is in the water, leaving the slipway or dry dock free for building or repairing hulls.



holding the model. This allows the naval architect to measure its resistance to the flow of water and determine the size of engine needed. Detailed building plans are then drawn up and sent to the shipyard.

Slipways

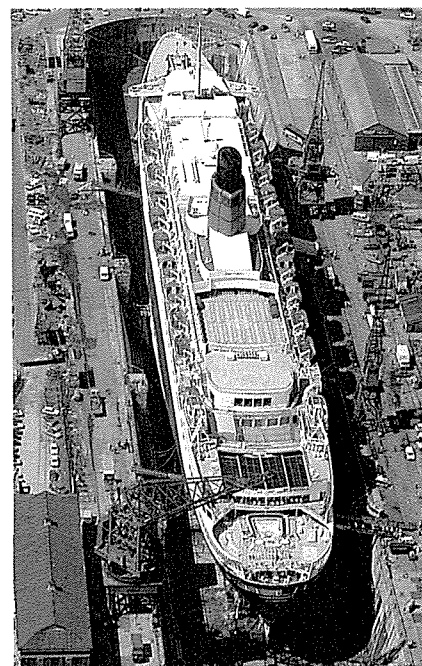
The traditional way of constructing ships, and the one still often used for smaller vessels, is on a sloping slipway. First, the keel is laid down and plates welded to it to form the ship's

bottom. Next, the main watertight bulkheads, cut by computer-controlled machinery to high accuracy, are fitted in place. These form the framework on which the side plates and decks are attached.

Launching

Finally, the curved stern plates are added and bent to shape by computer-guided hydraulic presses. The hull is then launched into deep water down the slipway.

Building and launching a vessel as big as a supertanker from a slipway



A dry dock is used when a ship needs repair. The ship is sailed in, the gates are closed and the water is pumped out until the ship rests on huge bilge blocks.

would be impossible, however. As the ship went down the slipway, the bow would still remain on land while the stern would be in the water. The central section would be hanging in mid-air with nothing to support it, and

so the ship would break its back.

To prevent this happening, supertankers are assembled, like offshore oil platforms, in specially built dry docks. These are giant concrete basins at the water's edge, sealed off from the sea by massive watertight gates. Some of the largest such docks are to be found in the shipyards of

REPAIRS AND REFITS

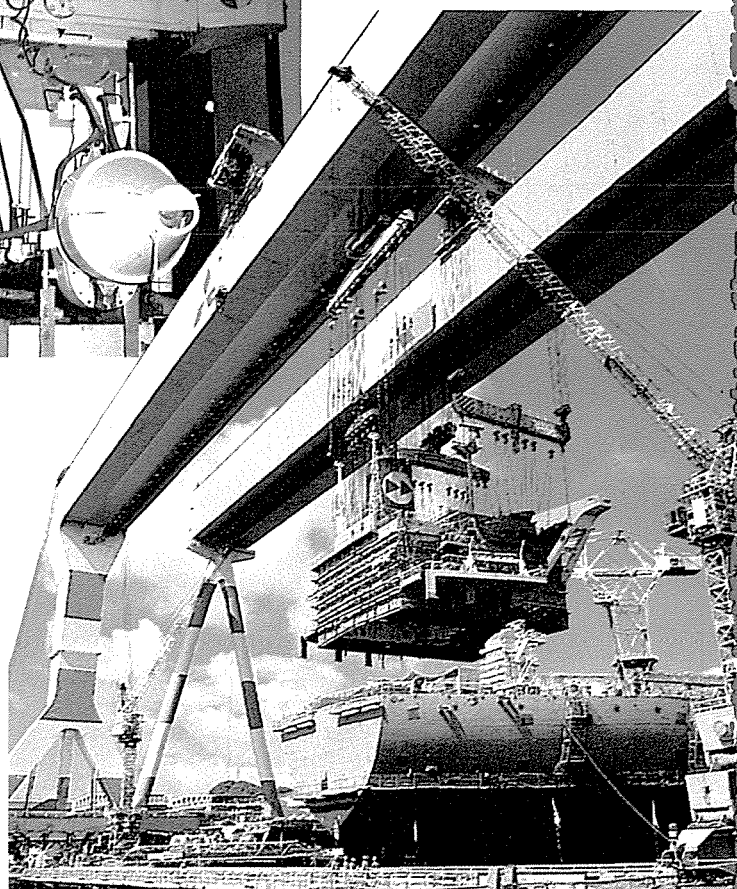
Each country that registers ships has strict rules about safety. These specify, among other things, when a ship must go into dry dock for inspection and repairs. With the ship's hull exposed, engineers check over the steel plating looking for cracks or signs of corrosion. The hull is thoroughly cleaned, repainted, and repaired by welding on new steel plates. Mud and other debris is cleared away from the propeller. During a complete refit, major items of equipment, including the engines, may be taken out and replaced.

Japan and South Korea.

One at Koyagi, Nagasaki, Japan, completed in 1972, can accommodate vessels up to a million tonnes deadweight. It measures 990 metres long by 100 metres wide. It is surpassed, however, by the 131-metre

The Goliath crane at Mitsubishi's Koyagi shipyard can lift up to 600 tonnes and moves up and down the kilometre-long dry dock on rails. This one is moving the entire superstructure of a ship into place in one piece. The steel plates used to make the ship's hull are shaped in a hydraulic press (above) which can exert a force of 8,000 tonnes.

Mitsubishi Heavy Industries Ltd



essary pipes, heating elements, and other equipment for handling the oil cargo, before being lifted and welded into position in the dry dock.

When the hull of the supertanker is complete, the ship is ready for fitting out. Engine, propeller and shaft, rudder, and countless other items of machinery are lowered into position. With the main deck in place, the superstructure is added, including the crew's quarters and bridge. Finally, the cranes and mass of scaffolding surrounding the ship are removed.

If the dry dock is large enough, the tanker will have been built in one piece. The dry dock is then flooded so

Mitsubishi Heavy Industries Ltd

Huge tanks in the walls of a floating dock are filled with water, sinking it so the ship can sail in. Then they are emptied, lifting the ship out of the water.

wide Daewoo Okpo Number One dry dock on Choje Island, South Korea, which can house tankers of up to 1.2 million tonnes deadweight.

Today, the trend is towards making large, prefabricated sections of hull under cover in an assembly shop alongside. Various parts of the ship can be worked on at once and jobs such as painting are not held up by bad weather. As each section is completed, cranes lift it into position while

welders fix it to the rest of the hull.

In some shipyards, the process of building section by section has been taken a stage further. Tracks link the assembly shop with the dock. The stern section is put together first, on the track inside the workshop. Then it is pushed along the track until only the edge to be joined to the next section is left inside. When the next section is ready, it is welded to the stern unit, and so on, until the ship is complete.



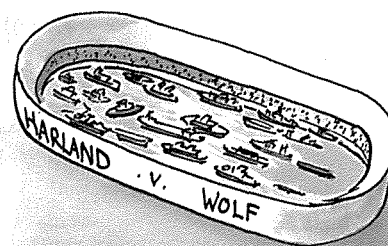
Modular construction

In some ways, building a supertanker is quite straightforward, despite the vessel's great size. The tanker is constructed from modular sections, each of which is fitted out with all the nec-

Just amazing!

SHIP AHoy!

THE WORLD'S LARGEST SHIPYARD, HARLAND AND WOLFF, QUEEN'S ISLAND, IN NORTHERN IRELAND, COVERS AN AREA OF 120 HECTARES – EQUIVALENT TO 176 FOOTBALL PITCHES.



Paul Raymond





The Norwegian ore carrier Berge Stahl is the biggest dry cargo ship in the world with a deadweight of 364,767 tonnes. Some oil tankers are bigger.

that watertight gates can be opened, allowing the sea to enter and float the ship. In other cases, a tanker may have been constructed in two separate sections, which are floated and welded together in the water.

After launch, the ship is berthed at a pier for final outfitting. In the case of, say, an ocean-going liner this would involve extensive work on passenger accommodation and facilities. But for a tanker it is a fairly minor undertaking, limited to such details as deck gear, lifeboats, and crew quarters.

The next stage is to run various tests on the supertanker while it is moored to the dockside. Checks are carried out to see that all electrical and

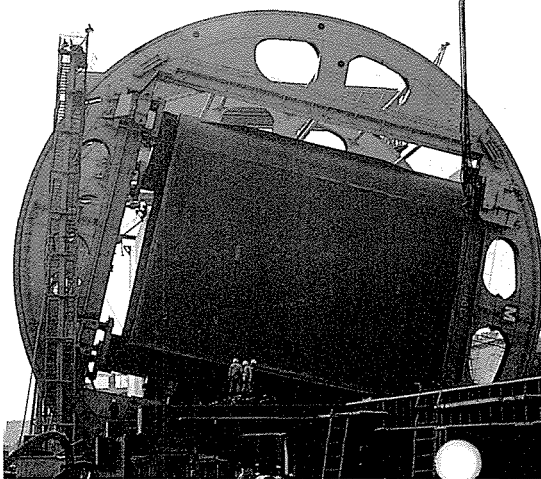
hydraulic systems, pumps, radar, computers, steering gear, and so on, are functioning properly. The engines are started and the propeller turned over at low speed while engineers monitor the performance.

Finally, the vessel is cast off and taken out for sea trials. In a series of tests, the tanker's speed is progressively increased until it reaches the maximum speed specified in the contract between the builder and the shipowner. Sea trials are conducted over a measured course of sheltered water, away from other sea traffic.



First cargo

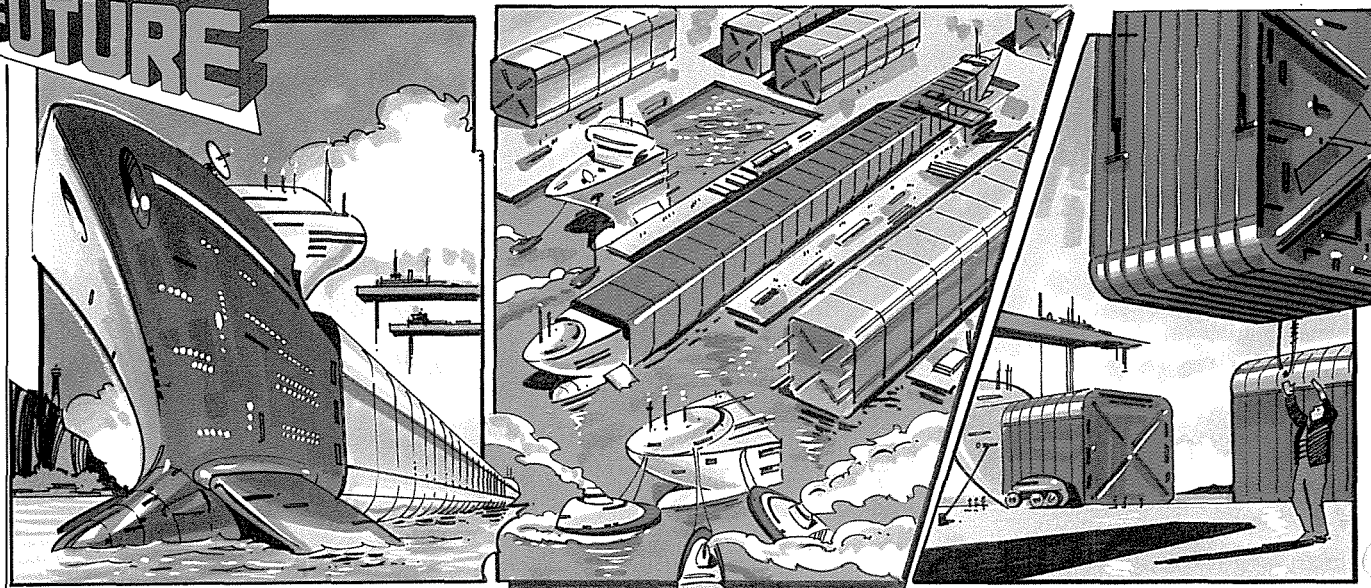
To simulate carrying a full cargo can be difficult for certain types of ship, but for supertankers it is easy: the tanks are simply filled with seawater. Finally, when the owner is satisfied, the supertanker, with its crew on board, sails away to load up its first real cargo of crude oil.



The Mitsui Rotas system rotates huge sections of an oil tanker while they are being welded. Then it slides them into their final position in the ship.

INTO THE FUTURE

SEA TRAIN



▲ Ships could soon be replaced by 'sea trains'. These would have a conventional bow and stern section, containing the engine and crew quarters.

▲ The mid sections, though, would be sealed cargo containers that would be marshalled like a train in a port. The bow and stern sections would then be added.

▲ When the sea train stopped off at port, new sections could be added and others removed – either to be joined to another sea train or opened if at their destination.

Q X-RAY STUDIES

Q INFRARED ANALYSIS

Q RADIOGRAPHY

TRUE

OR FALSE

?

FAKE OR REAL: WITH FAMOUS paintings and other works of art fetching millions on the international market, forgery is a big problem. To avoid embarrassment and loss of money, museums and art galleries are turning to an increasingly powerful array of scientific instruments to establish authenticity.

Forgery is not new – Roman sculptors copied classical Greek statues and sold them as originals, 2,000 years ago. Nor is the use of technology to analyse art all that recent – one of the first objects William Roentgen examined with the X-ray machine he invented in 1895 was a painting.

Probing instruments

But in the past few years, techniques that can probe an art object at levels invisible to the human eye have become far more sensitive. At the same time, the high demand for art has led to a rise in the number and sophistication of forgeries.

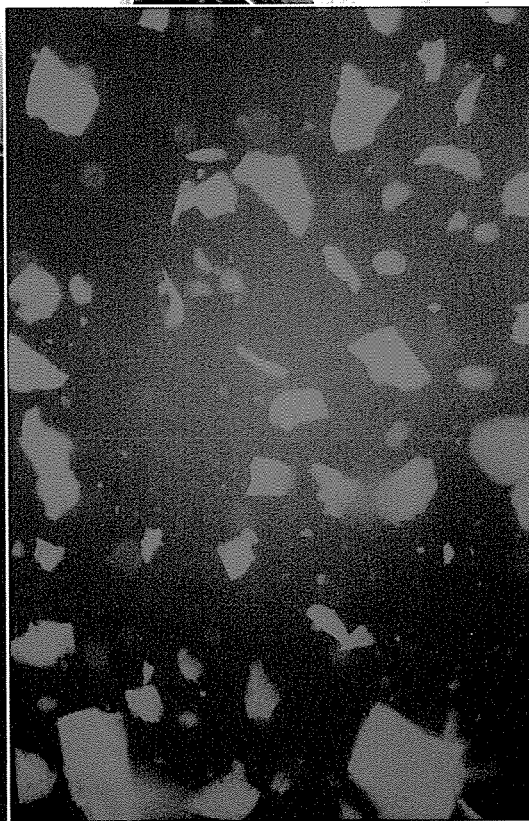
Most methods used to detect forgeries have not been developed specifically for that purpose. Instruments that can probe, non-invasively beneath the surface of a painting, for example, are used mainly by art experts for finding out more about the

history, techniques and materials of genuine masterpieces.

In a technique called infrared reflectography, the painting is bombarded with infrared rays from lamps, and then viewed through a camera equipped with an infrared filter. The infrared light waves penetrate the various layers of pigment but are reflected by any charcoal or metal point underdrawing that lies beneath the surface of the paint.

Photographing a painting with

An expert at the Louvre in Paris examines the X-ray of a painting for details of draft sketches and overpainting that might reveal the masterpiece as a fake. Ultraviolet light is also used to study varnish and pigments (inset).



Conservation Dept., Tate Gallery London



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2



3



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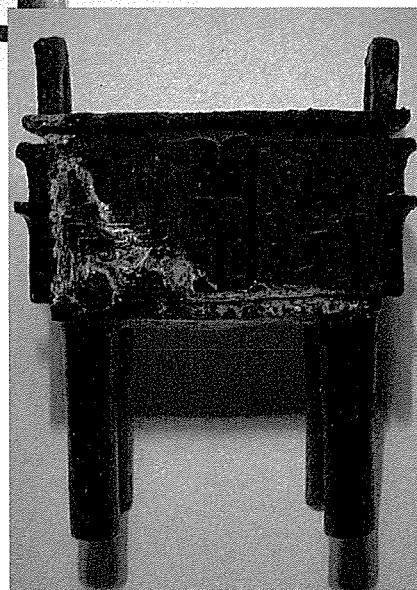
Hidden self-portrait of Van Dyck. The original (1) reveals hints of a face under X-ray (2). A few hours after irradiation with neutrons, manganese in the base appears (3). Four days later, phosphorus in the charcoal sketch shows up (4), best viewed upside down.

The results of such infrared and X-ray studies often prove surprising. X-ray photographs taken at the Los Angeles County Museum of Art of a 17th century Flemish masterpiece, for example, called *The Crucifixion*, showed that beneath the surface lay an entirely different painting.

Trustees of the British Museum



This Chinese bronze vessel appears totally genuine under ordinary light. But X-rays revealed a crack, clumsily repaired with solder. Ultraviolet light shows that the repairers have faked part of the decoration with a new and different patina (below).



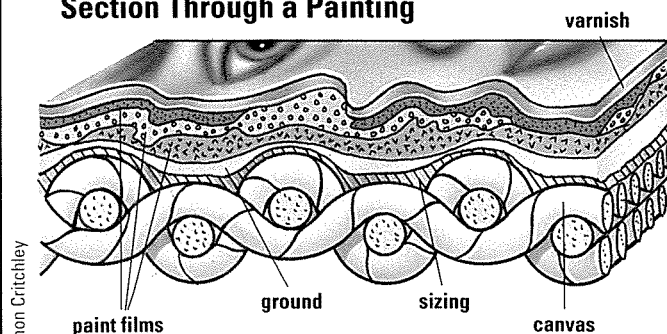
Trustees of the British Museum

X-rays, though, can reveal intermediate layers of paint between the first sketch and the top layer of varnish. Low-energy X-rays are reflected by the top coat of paint, while high-energy X-rays penetrate to deeper layers.

Recently, the use of digital video cameras has made these methods still more powerful. A digital video camera assigns a number value to the brightness at each point in a picture. This data can then be fed directly into a computer so that the image can be processed in various ways.

For instance, the information in a low energy X-ray photograph of the top layer of paint can be subtracted

Section Through a Painting



Simon Critchley

Different layers of a painting yield clues to the forgerly detective. Over the years different types of top surface varnish, paint, canvas and size have been used. They all degrade differently over time.

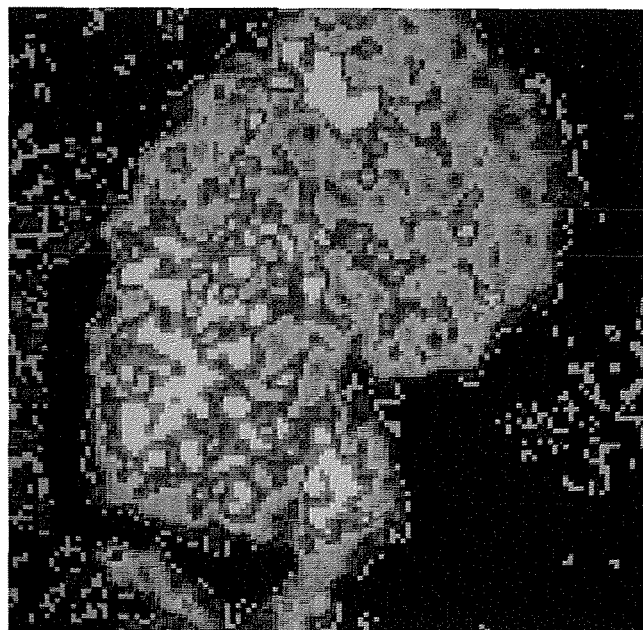
from a high-energy X-ray image of a lower layer. The result is a much clearer view of what lies below the surface. The computer can even subtract the effects of the cracking of glazes or the grain of wood.

Even the greatest artists changed their minds during the course of a particular work. Detail that may appear in the original sketch, as shown by infrared photographs, is often missing or greatly altered in the final painting.

Sometimes these analysis techniques prove that a lesser artist painted what previously had been credited to a great master. Using an infrared camera at the Isabella Stewart Gardner Museum in Boston, an expert spotted a signature on a work thought to have been by Rembrandt. The signature, in fact, belonged to one of Rembrandt's students.

Analysis by infrared and X-ray has shown that many paintings supposedly by Rubens were only started by him, then given to his students to

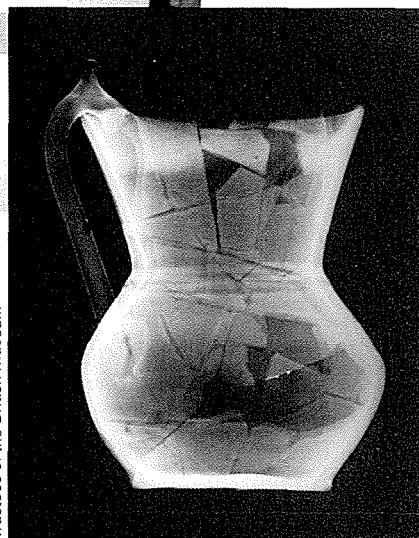
A digital false colour X-ray image of a gold brooch from Lombardy reveals the presence of cadmium, a constituent of modern gold solders. This shows that it could not have been made in the 17th century as claimed.



Trustees of the British Museum



The British Museum's X-ray machine showed that a jug previously thought to be genuine was a collection of pieces stuck together and repainted (right).



Trustees of the British Museum

complete. Far more damaging to the international art market, however, are the hundreds of paintings once thought to be valuable masterpieces that, when examined rigorously with modern technology, have proved to be recent fakes.

Although a painting may convince the art experts that it is a genuine masterpiece, photographic analysis may show that the sketch underneath is

completely different in style and done by a forger. But the skill of many forgers means that more powerful methods are often needed to decide what is genuine and what is fake.

Radiography

Providing information about the distribution of different elements and the pigments they make up, neutron-activation radiography involves placing the painting in a beam of neutrons coming from a nuclear reactor. Neutrons – tiny, uncharged particles produced in huge numbers during the break-up of radioactive substances – are absorbed by the paint; and each element in the painting re-emits gamma rays – high-energy rays – at a unique and recognizable wavelength. Captured on photographic plates, these gamma rays reveal the type and amount of each element present.

Since the use of specific pigments

Complex computer-designed laser-generated patterns are added to the background of banknotes to make them more difficult to forge.

is often characteristic of specific periods or specific artists' work, this method can be used to spot extremely sophisticated forgeries. Among other things, it can determine whether a painting thought to be of 19th century origin contains, say, titanium white, a pigment which was first manufactured in the 20th century.

Another method of examining the make-up of oils and resins in paint, which helps establish the period from which a work of art dates, is laser fluorescence spectroscopy. When a laser is directed on to a painting the oil and

CASHING IN ON FAKES

Recently, in Canada, a man was caught making counterfeit money with the help of a full-colour laser copier that he bought for US\$47,000. The fake Canadian and American banknotes that he produced on the machine were virtually indistinguishable from the real thing. But in the future passing off forged money is likely to be much harder. A Canadian researcher, for example, has perfected a method for coating banknotes with a thin, flexible film of coloured metal. These iridescent films, only a tenth of a micrometre thick, produce patterns that vary according to the angle from which they are viewed. By tilting such a banknote it would be easy to see whether or not it was a fake.

resin molecules fluoresce, or give off light at special wavelengths that reveal their composition.

Sculptures are notoriously difficult to authenticate. Sometimes a forgery may give itself away by slight discrepancies in style or condition for its supposed age. But usually the expert has to turn to highly specialized methods of analysis. One of these involves taking photographs through a microscope, digitizing the images, then examining the results with a computer. Tiny irregularities in the surface of



the material can help to distinguish a good copy from the real thing.

In 1984, the Getty Museum in California had to decide whether or not to buy a Greek marble figure of a youth, said to date from about 530 BC.

Customs officials in Los Angeles use a steamroller to crush a batch of fake Cartier watches. Many imitations of famous brands are made in the Far East.

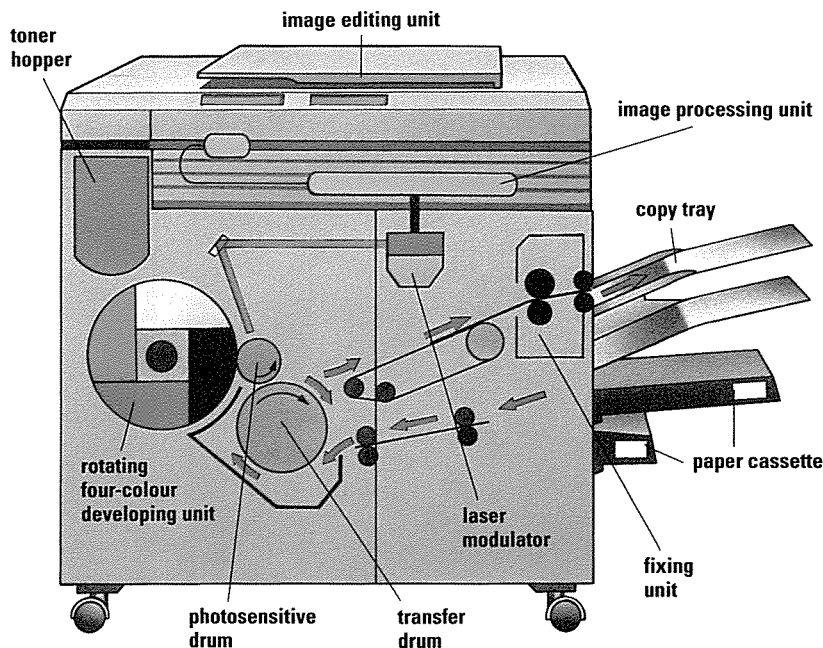


Gamma/Frank Spooner Pictures

Some experts had suggested that it might be a fake, partly because it was in such good condition.

During a thorough study of the piece by the museum, a tiny core sample, 1 centimetre across and 2 centimetres long, was taken from a crack in the figure's right knee. The marble crystals in this were then compared with crystals

COUNTERFEITING MADE EASY



A semiconductor laser is used to reproduce images in a laser copier. To prepare for copying, the photosensitive drum is exposed to electricity to build up a uniform charge on its surface. Signals sent from the reading unit, which scans the original image, activate the laser, turning it off and on. When the

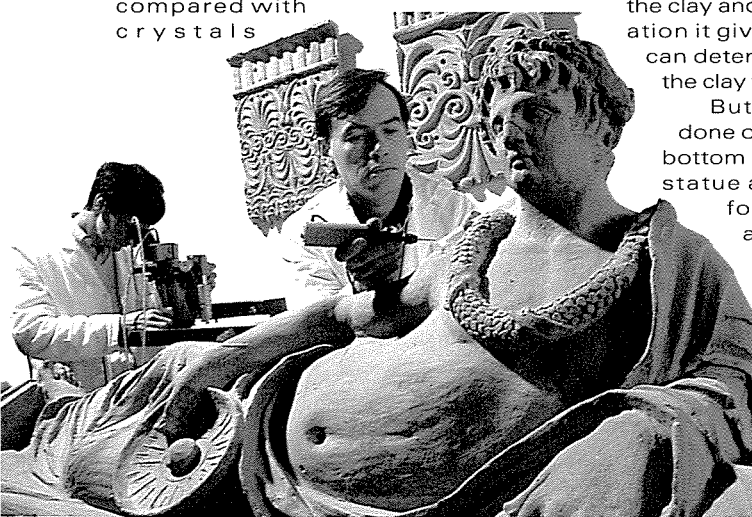
laser is on it strikes the drum, partially neutralizing the charge. Areas not struck keep their charge. The partially neutralized areas attract toner, which is then transferred to paper to make the copy. The drum is recharged four times, once for each toner colour – yellow, red, blue and black.

Steve Latibeaudiere

make progress. A technique known as thermoluminescence dating provides a good example. This method exploits the fact that clay absorbs radiation with time. It releases this radiation when heated so, by heating the clay and measuring the radiation it gives off, art scholars can determine roughly when the clay was last heated.

But the test is usually done on a sample from the bottom of the leg of a pot or statue and, knowing this, forgers often glue an ancient leg on to a modern piece. Another, equally

dip sculptures in acid or bury them in dung heaps to produce an ancient-looking coating or patina. He may employ lasers to map the surface of an old coin and then micromachine the same surface on to a fake coin. Or the forger may use the latest photocopying or high-quality printing technology to make bogus prints. As the stakes rise, the battle between expert and forger looks set to intensify.



taken from the surface of a statue of an authenticated date that had been subjected to aging and weathering. From this and other tests it was decided that the statue was genuine and that the museum should buy it.

As the experts use more and more sophisticated methods of detecting forgeries, so the forgers themselves

devious, trick of the forgery trade is to beam X-rays at a ceramic piece to boost its radiation content and, therefore, its apparent age.

Determined criminals can also learn exactly what materials and methods the original artist used, often by reading the same scientific journals as the art experts. The forger may

Engineers at the Louvre take a tiny sample of the marble from an Etruscan sarcophagus to check it was made in the 11th century.

Just amazing!

FORGING A HEAD

PARISIAN ARTIST ANTONIO BIN HAS PAINTED THE WORLD'S MOST FAMOUS PORTRAIT, THE MONA LISA, AT LEAST 300 TIMES. HIS HONEST FAKES SELL FOR UP TO \$1,000 EACH.



Paul Raymond

 HUMIDITY DAMAGE

 POLYMERS

 ACID PAPER

WORLD PRESERVATION



The Sphinx, Egypt, under an imaginary protective cover. Computer-generated imagery shows a movable canopy for shelter from the elements.

PRICELESS WORKS OF ART all over the world are under constant threat from the environment, malicious vandals, and professional art thieves. The challenge to art conservators is to find better methods of preserving items of historical value.

Very old paintings are especially vulnerable to large changes in hu-

midity, or the concentration of water vapour in the atmosphere.

Before about 1450, most European paintings were done on wooden panels, which swell and shrink across the grain as the humidity varies. In Britain, for example, the humidity in a museum or gallery can vary from 25 per cent in midwinter to 90 per cent in summer. As the wooden support bows and shrinks, the

paint on the surface cracks in a fine network called craquelure.

The problem can be made worse if a wood-panel is moved to a location with very different atmospheric conditions. In certain parts of the United States, for instance, the average humidity is low all year round, so that a European painting used to a higher humidity may be badly affected. The best solution is to air-condition

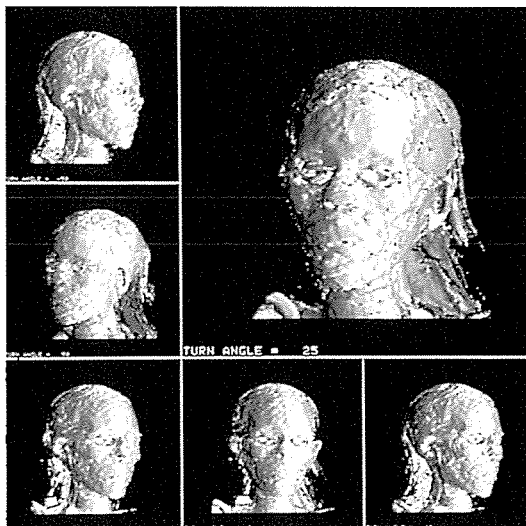


the area in which the painting is to be stored or displayed. The air-conditioning keeps the humidity more or less constant at the least-damaging level, usually around 55 per cent. For the same reason, furniture and canvas paintings are best kept in an air-conditioned environment.

Human damage

Occasionally, a vandal will launch a mindless attack on a piece of art, throwing acid over a painting or striking a sculpture with a hammer. But visitors to museums, art galleries, and historical sites can also cause serious damage without realizing it.

Simply by breathing in an enclosed space, people cause the humidity to rise. Many of the wall paintings in Egyptian tombs have begun to flake



A computer-generated image of a female Egyptian mummy. Compiled from computer tomography X-ray data, it was obtained without having to open the precious coffin.

as weak acids. Sulphur dioxide is especially damaging to stone. It reacts with the mineral calcite, contained in marble and limestone, to produce a surface layer of gypsum. Unlike calcite, gypsum will dissolve in water. So, when it rains hard, the gypsum surface layer is washed away, leaving the fresh stone underneath bare to renewed attack.

By this process, decoration on the Acropolis in Athens is

being eroded faster now than at any other time in the building's 2,300-year history. Similarly, frieze panels on the Parthenon have lost much of their detail because of sulphur dioxide in the smog over the Greek capital. A panel taken from the Parthenon and stored in the British Museum since the early 19th century, by comparison, shows relatively little sign of weathering.

As well as damaging stonework, chemicals in the atmosphere can cause discoloration. This happens when soot and ash become trapped in the surface layer of stone as it is chemically transformed. The first task

off because of the hundreds of visitors that have crowded daily into the enclosed spaces, moistening the air with their breath. In cases like this, there are two possible courses of action: to install air-conditioning or limit the number of tourists allowed.

An unblemished angel, as it appeared when first created in 1880 for Cologne Cathedral. Now, sulphur acid rain has dissolved the stone, and dirt on the surface contains a lot of calcium sulphate, which cannot be removed without damaging the stone. Algae live on organic dust and nitrogen given off by traffic. Their metabolic products also help to dissolve the stone.

Cologne Cathedral



A ravaged angel in need of restoration. The effects of industrial pollution on the soft limestone are intensified because of its exposed position.

RIDDLE OF THE SPHINX



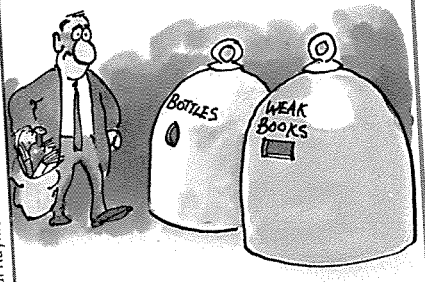
A 90-kilogram, 2-metre-tall instrument on the back of the Great Sphinx in Egypt may help to solve a modern riddle about the half-human, half-lion structure: why is it crumbling? Between 10 and 30 centimetres of the surface of the Sphinx are wearing away every century. The instrument contains sensors that collect information every 10 to 15 seconds on wind speed and direction, rainfall, humidity, condensation, air temperature, solar radiation, and the surface temperature of the Sphinx. By examining this data, scientists hope to decide which of several possible processes may be causing the deterioration. These processes include rising ground water, erosion by wind and sand, and wide fluctuations in temperature.

Gamma/Frank Spooner Pictures

Just amazing!

BRITTLE BOOKS

90 PER CENT OF BOOKS PUBLISHED IN AMERICA BETWEEN 1900 AND 1949 WILL BE TOO WEAK FOR GENERAL CIRCULATION BY THE YEAR 2000.



Paul Raymond

Sightseers have brought a different kind of threat to murals and sculptures at Mayan remains in Mexico. At one major site on the Yucatan Peninsula, known as Tulum, buses are parked directly in front of the entrance with their engines running for hours. The powdery black soot they give off coats the paintings and stone sculptures already damaged by another atmospheric pollutant coming from nearby oil wells – acid rain.

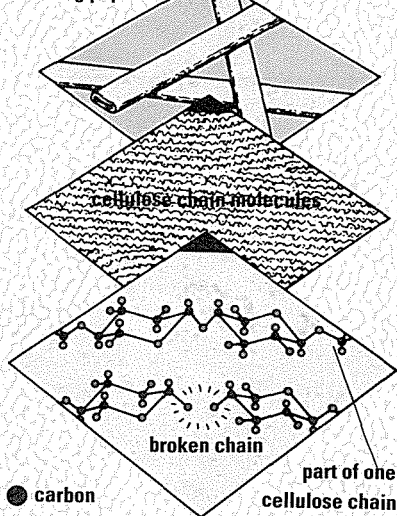
Sulphur dioxide

From the cathedrals of France to the ancient temples of Greece, some of the world's most prized stonework is suffering severe damage from air-borne pollution. Oxides of sulphur and nitrogen are produced when oil, coal, or natural gas are burned, such as in car engines and power stations. These oxides then mix with water vapour in the air and fall to the ground



Acidic Weakening of Paper

flattened, bonded fibres
in strong paper



Gamma/Frank Spooner Pictures

D J Priest/Paul Williams

The slight acidity of wood pulp used to make paper eventually attacks the molecule chains of the cellulose backbone that gives paper its strength and results, over time, in brittle paper.

in protecting a sculpture or building from further decay, then, is to clean it and remove unwanted substances from the surface. This can be done by brushing the stone or blasting it with air, water, steam, or grit.

Next, the cleaned, exposed masonry is treated. One of the most effective

means of a curing agent. Some of the polymers used today not only bind the particles of stone together, they provide additional protection by repelling water from the surface.

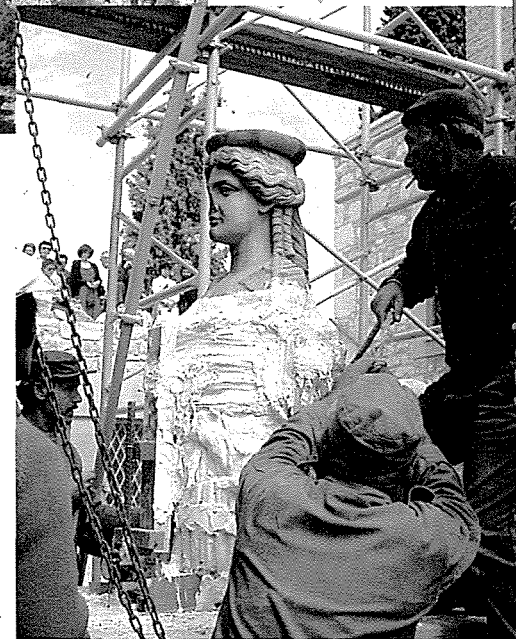
Stained glass

Mediaeval stained-glass windows are particularly fragile and prone to damage. The usual method of protecting artwork inside a building, by air-conditioning and other environmental controls, is impractical inside a cathedral or church. Instead, the best solution is to use double-glazing.

A protective pane of glass, not attached to the stained-glass panel, is installed on the outside. Then, the temperature and humidity of the air gap between the panes is carefully controlled. The result is that the new, protective window absorbs changes in the outside temperature while at the same time collecting moisture. Meanwhile, the stained glass stays uniformly warm and dry.

In great libraries and archives millions of books are literally falling apart because of a new way of making

Sipa Press/Rex Features Ltd



WELL PRESERVED

'Nefos' – the Greek for cloud – is the name given to the smog that hovers over Athens, one of the world's most polluted cities. When the pollution is severe, hospital admissions rise.

A Caryatid – a draped female figure used as an architectural support instead of a column – exhibiting the effects of pollution at the Acropolis in Athens, Greece.

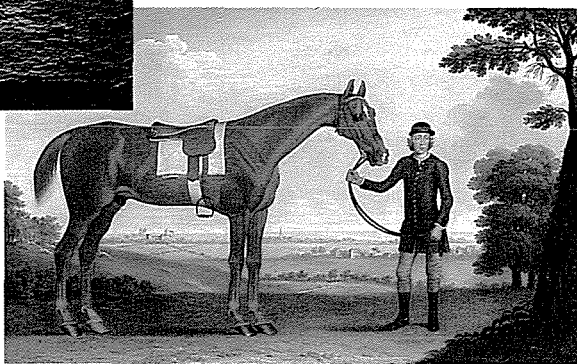
or linen rags that were used before.

Unfortunately, book publishers did not know that the wood pulp's slight acidity would eventually prove disastrous. The acid attacks the long chains of cellulose molecules in the paper, making them shorter and shorter until the paper decomposes.

Book preservation

The necessity of book preservation, therefore, needs to be applied on three fronts. The first is to see that the printing industry adopts acid-free paper for books. The second is the conservation of books that are already too brittle for use. Methods employed in this category include microfilming used for long runs of brittle books and newspapers and digital optical discs used by the Library of Congress, US, for recent, short, high-use articles and reports. Traditional methods of hand conservation are used for artefacts of special importance. This process is expensive and time-consuming as it involves washing out the acid in water and then providing an alkaline buffer to a text block which has been pulled from its

Changing humidity is the main cause of the cracks in this painting by James Seymour. They are made more pronounced (above) by photographing using 'raking light' to show underlying defects.



Conservation Dept, Tate Gallery, London

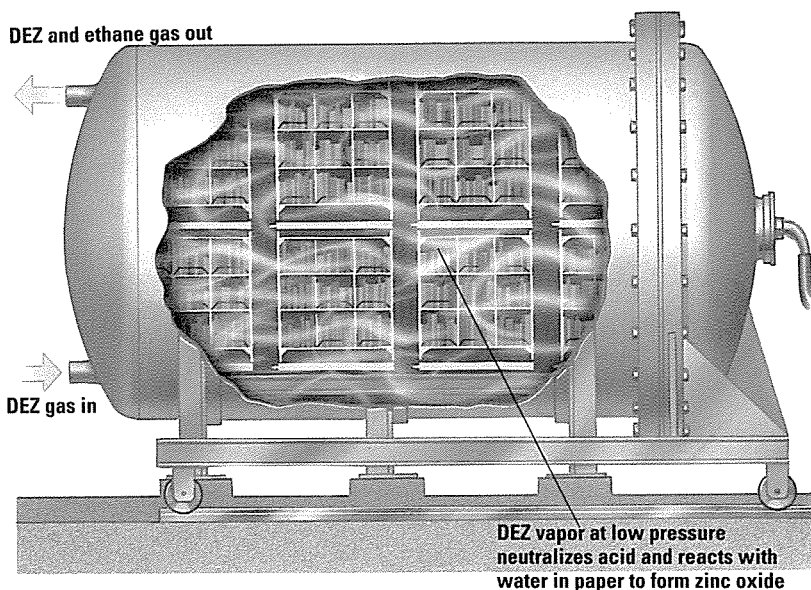
ways to do this is with substances known as organic monomers or pre-polymers. These are introduced into the stone, then made to polymerize, or join into long molecular chains, by

paper that was introduced in the middle of the last century. In this process wood pulp became the main source of the cellulose from which paper was made, replacing the cotton



LIFE SAVER FOR CRUMBLING BOOKS

Akzo Chemicals/Paul Williams



Deacidification is a process of treating books with diethyl zinc gas (DEZ) to preserve them by neutralizing the acids in paper that make books decay. DEZ changes acids present to neutral salts.

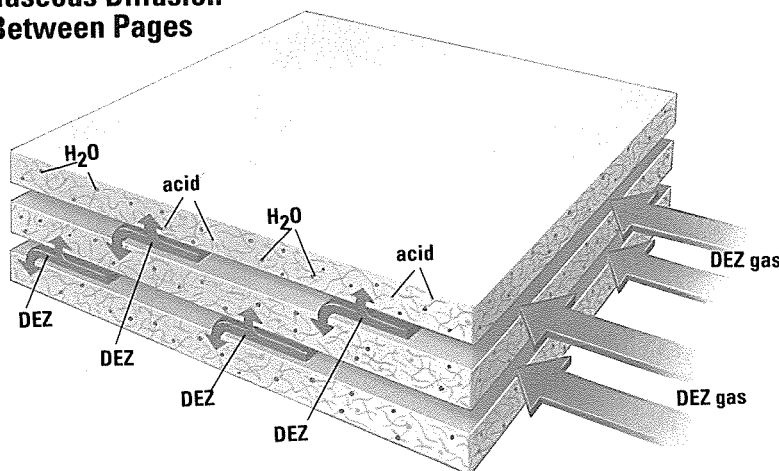
Books to be treated are placed in a closed chamber and the air is removed to produce a vacuum. Water, normally present in paper, is reduced by the vacuum and slight heating. The DEZ gas is then introduced into the chamber and allowed to remain until existing acids have been neutralized. The neutralizing occurs because DEZ reacts with acid molecules to form zinc sulphate and ethane gas. Zinc oxide is formed by the reaction of the gas with residual water, and this neutralizes any acids that may form in the future.

This process takes about 60 hours and increases the life of the paper up to five times. The cost per book is £2, a substantial saving compared to micro-filming, which costs £40 per book.

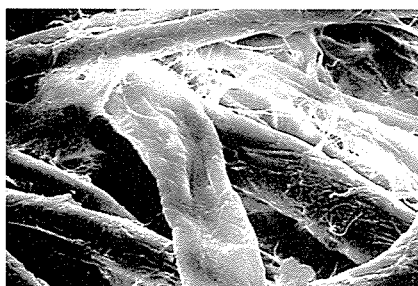
binding and will need to be rebound.

Two new methods of preserving books are a process called deacidification, developed by the chemical company Akzo in conjunction with the Library of Congress, and a system

Gaseous Diffusion Between Pages



Filter paper before treatment with the paper-strengthening process being developed at the British Library, London, UK. The fibres are clearly visible.



Polymer deposits have coated the individual paper fibres after the strengthening process has been carried out. Polymer is also stretched between paper fibres.

A security system for the protection of artworks. The screen shows an X-ray reading of a coded implant inserted in the painting, details of which are kept in a strongroom in Geneva.

currently being researched at the British Library. Deacidification is mainly for preventing the decomposition of contemporary books as it does not restore the strength of damaged paper and is therefore only suitable for books that retain enough strength. This system, using a gas, aims to eliminate the acid content of the paper and to deposit an alkaline buffer against future attack (see LIFE SAVER above).

The method being researched by scientists at the British Library on the other hand, as well as treating paper to retard degradation, restores some strength. A polymer is deposited within the underlying mesh of the paper, so helping to strengthen and protect the individual fibres. A polymer is a substance with very large molecules, which are built up from a series of small basic units (monomers).

A monomer mixture is introduced into a container holding the books. The container is then irradiated with a low dosage of gamma rays, which convert the monomers into polymers. Individual paper fibres are coated with polymer and polymer is also stretched between paper fibres. The books are thus protected against acid attack and also strengthened without adding significant bulk.

GLOBAL GARBAGE CRISIS

EVERY CITY OF THE WORLD IS overrun with rubbish. So much is produced that it is almost impossible to get rid of it all. There are just not enough places to bury it.

In some places better use is made of this domestic waste by burning it and using the heat produced to generate electricity. Incinerating rubbish in special plants costs £20 a tonne compared with £15 a tonne to bury it. But the electricity generated is worth £10 – giving a profit of £5 a tonne. It is estimated that if all domestic garbage were handled this way it would provide 10 per cent of electricity needs. However, simply by extracting the glass from one tonne of domestic waste and taking it to the bottle bank saves more energy. Added to that the fact that some domestic waste is



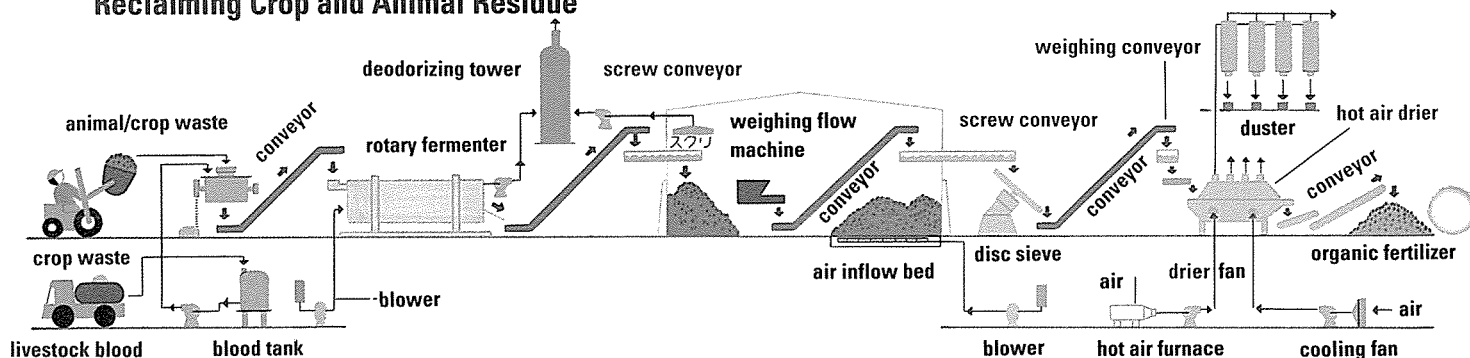
Huge amounts of energy are wasted if scrap metal is not recycled. Making one tonne of aluminium from ore, for example, uses enough energy to recycle 20 tonnes of scrap aluminium.



Landfill is no solution. Most cities are quickly running out of sites and the organic matter in buried rubbish creates methane – a powerful greenhouse gas.



Reclaiming Crop and Animal Residue



found to give off the cancer-causing chemical dioxin when burnt, it seems that recycling is the real answer to the global garbage crisis.

To make one tonne of paper, it takes the wood from 17 trees, 5,000 kilowatt-hours of energy and 130,000 litres of water. The trees

alone take 55 years to mature. All that goes to waste if it is thrown away.

But if the paper is recycled, to make one tonne of new paper, the wood from only one or two new trees is needed to add new fibre for strength. Only 1,100 kilowatt-hours of energy and 130,000 litres of water are needed. This is a great saving. However, only 25 per cent of the world's paper is recycled.

Paper exchange

In many parts of the world, paper is collected separately from other household garbage. In Tokyo, for example, you cannot buy toilet rolls – you have to hand in your old newspa-

Crop waste is reclaimed by mixing it with livestock blood and other slaughter-house waste. The mixture is then fermented, dried and, after the removal of rough lumps, it is used as an organic fertilizer.

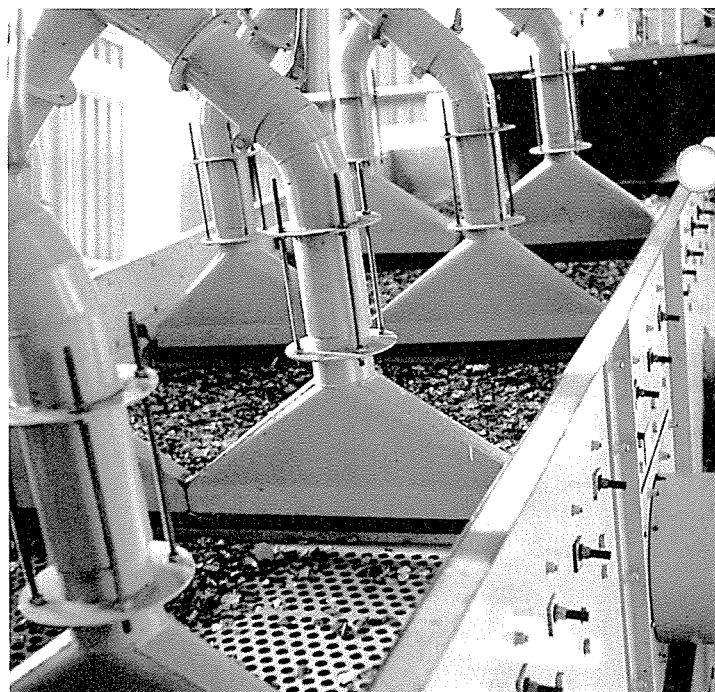
1989, on two kilometres of beach on an uninhabited island in the Outer Hebrides off Scotland, over 100 plastic objects were found – half of them plastic containers. In the middle of the Pacific Ocean, over 900 km from the nearest civilization and outside the main shipping lanes, over three plastic items an hour were found floating.

A recent survey found that one in

Clean Japan Centre/Andrew Shaw

New bags from old. Clear new polythene is extruded from recycled waste. Old polythene is processed into pellets which are soaked in hot water, then blown out into a plastic tube by hot air.

Crushed glass from bottle banks is used as cullet, a fluxing agent used to help melt the raw materials when making glass. Adding cullet reduces the amount of energy required. But the glass must be pure – free of stones or foreign bodies.



United Glass Ltd

Just amazing!

HIGH-RISE RUBBISH

IN THE UNITED STATES, THE AVERAGE CITY DWELLER DISPOSES OF WELL OVER A TONNE OF DOMESTIC GARBAGE EVERY YEAR.



Paul Raymond

pers to get toilet rolls in exchange.

Every year over 150,000 tonnes of car tyres – made from synthetic rubber – are thrown away, and the energy used to make them is lost. On top of that, the 400,000 tonnes of man-made plastics and more than 175,000 tonnes of cellulose-based plastics that are used to make clothes, carpets, upholstery, and other synthetic fibres are thrown away every year. Only one-tenth is reclaimed.

Synthetic rubber and plastics cannot be burnt without creating noxious gases, and they are not very 'biodegradable' – left out in the environment, they do not break down. In

five plastic objects found on the coast was over five years old – though none was over 14 years old, giving hope that, in time, plastics do break down.

Choked to death

Still, in their lifetime, plastics can cause devastation. In 1977, a joint American and Russian report found that some 8,000 fur seals were fatally affected by waste plastics. They died slowly from starvation, strangulation, drowning or infection. Similarly, cows, sheep and horses have all died after eating plastic bags. An elephant in Munich Zoo has choked to death on a plastic cup thrown into an enclosure.



ATOM SMASHING

CHAIN REACTIONS

MELT-DOWN

NUCLEAR POWER

The nuclear power station at Oldbury, in Gloucestershire, UK, generates electricity and supplies Britain's national grid throughout the day and night.

THE AWESOME ENERGY unleashed by a nuclear bomb can destroy a city within seconds. But nuclear energy can also be released gradually for peaceful purposes – to supply us with electricity and propel ships and submarines.

All atoms consist of a relatively heavy nucleus surrounded by a cloud of tiny, negatively charged electrons. The nucleus is made up of positively charged protons and electrically neutral neutrons, which are bound together by powerful nuclear forces. As a result, most types of nuclei are stable and extremely hard to split apart. But this is not the case with the nuclei of some very heavy atoms.

Uranium-235

Uranium is the heaviest naturally occurring element on Earth. Most uranium is of a type called U-238. The nuclei contain 92 protons and 146 neutrons. Nuclei of U-238 are difficult to split apart artificially. But about one in a hundred atoms of natural uranium are of a different type: U-235.

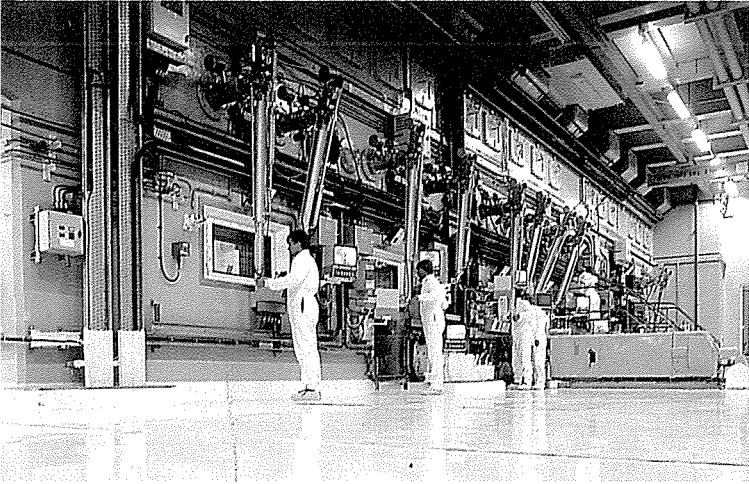
If a particle such as a neutron collides with a nucleus of U-235, the nucleus may shatter into two large

An engineer checks equipment inside a nuclear power station. Some of the pipes convey a liquid or gas, which transfers heat from the reactor to the station's steam generating stages.

Martin Bond/Science Photo Library

Gamma/Frank Spooner Pictures





British Nuclear Fuels

fragments plus a number of smaller, fast-moving particles. Among these released particles are neutrons that can then go on to split apart other U-235 nuclei, and so on. The splitting apart of a nucleus is known as fission, and the process by which fresh particles cause further fission is called a chain reaction.

Controlling a chain reaction is all-important. If the chain reaction in a lump of uranium gets out of control, the result is a devastating explosion. On the other hand, if the U-235 nuclei are spread too thinly, it may be impossible even to start a chain reaction.

Fuel elements

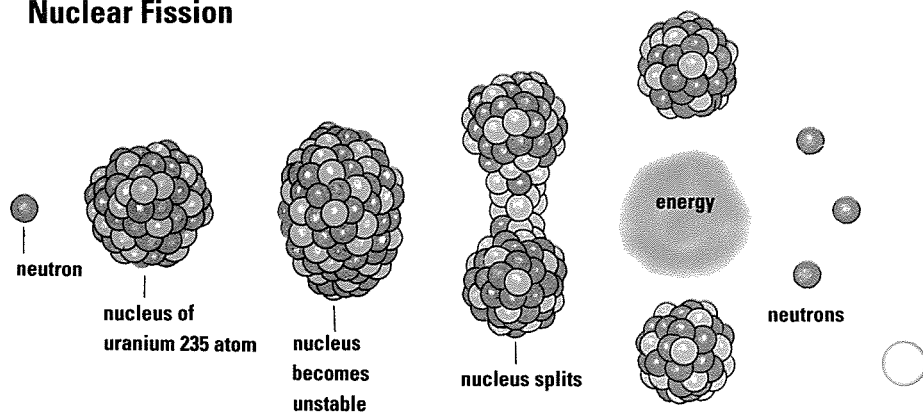
In most reactors, the concentration of U-235 is boosted from about one per cent, as it occurs in nature, to about three per cent. The enriched uranium, usually in the form of uranium dioxide, is loaded into narrow tubes, called pins, measuring several metres long. Up to 200 pins are mounted side-by-side to form a cylindrical fuel element, ready to feed into the reactor.

The chain reaction is started by bombarding the fuel elements with neutrons. The reaction is kept at the right level by controlling the flow of

they bump into other U-235 nuclei. The moderator surrounds the fuel elements in the reactor core.

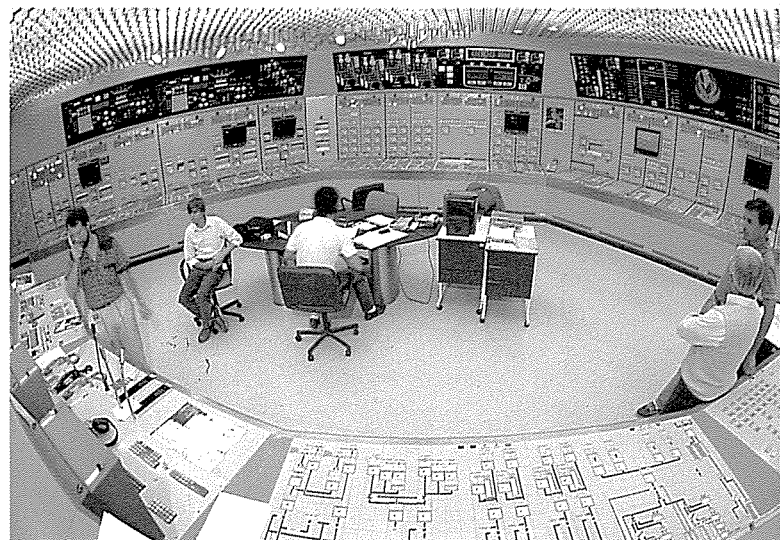
To alter the rate of the chain reaction, control rods are pushed in or out of the core. These rods, made of a neutron-absorbing material, soak up

Nuclear Fission



Nuclear fission, or splitting, of a uranium-235 atom starts when it is struck by a neutron. The atom becomes unstable and then splits, releasing energy and more neutrons.

Electronic control and monitoring play a major part in the operation of a nuclear power station. The equipment enables engineers to keep a continuous check on all processes.



THE HYDROGEN BOMB

Nuclear energy can be used for peace or for the most deadly of all purposes – nuclear war. Atomic bombs – the first nuclear weapons – worked by setting off an uncontrolled fission (splitting) reaction in a small mass of uranium. Nuclear weapons today, however, rely on the even more awesome power of nuclear fusion – the smashing together of lighter nuclei to make heavier ones. In this process, which usually involves hydrogen nuclei fusing to form helium nuclei, a tremendous amount of energy is released. But to trigger the fusion reaction, temperatures as high as 100,000,000°C are required. An atomic bomb trigger provides the sudden injection of heat required to set off the nuclear fusion reaction.

free neutrons. When a U-235 nucleus breaks up, the neutrons that escape are travelling very fast. These have to be slowed down by a material called a moderator so that they have a better chance of causing fission when

neutrons and so reduce the number available for causing fission.

As the fast-moving neutrons produced by U-235 fission split other nuclei inside a fuel element, a great deal of heat is produced. This heat is carried away by a coolant that is pumped through a gap between the fuel element and the moderator. If the flow of coolant were to stop, the fuel elements would quickly overheat and turn to liquid – a dangerous condition known as 'melt-down'.

NUCLEAR ENERGY

Country	Electricity from nuclear energy
France	70%
Belgium	67%
Sweden	50%
Switzerland	39%
Germany	30%
Spain	29%
Japan	25%

Two different designs make up the bulk of reactors currently in use. The advanced gas-cooled reactor (AGR), popular in the UK, employs a gas coolant and a graphite moderator. In the pressurized water reactor (PWR), water serves as both the coolant and moderator. Because the water is kept

at a very high pressure inside a thick-walled steel vessel, it does not boil, even though its temperature rises to about 300°C.

Steam turbine

In both types of reactor, the coolant then passes through a heat exchanger, where its heat is used to turn water into steam. The steam drives a turbine, which spins a generator to produce electricity.

After several years in a reactor, the

Gamma/Frank Spooner Pictures



U-235 in the fuel becomes exhausted and has to be replaced. But the spent fuel elements are not wasted. They go to a reprocessing plant, such as the one at Sellafield in Cumbria, UK, where useful uranium and plutonium are extracted. The plutonium is

This pressurized water reactor uses high-pressure water to transfer heat from the reactor core to four steam generators. The steam drives turbines.

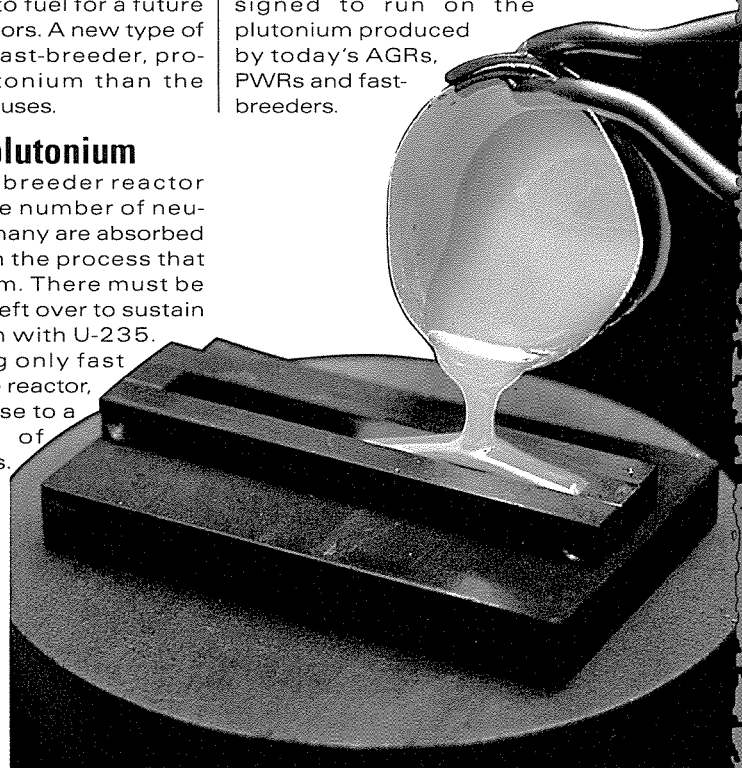
produced when neutrons inside the reactor collide with the non-fissile form of uranium, U-238.

Plutonium is used in nuclear weapons. So some of the plutonium from reprocessing plants goes to supply the defence industry. The rest is stored or made into fuel for a future generation of reactors. A new type of reactor, called a fast-breeder, produces more plutonium than the amount of U-235 it uses.

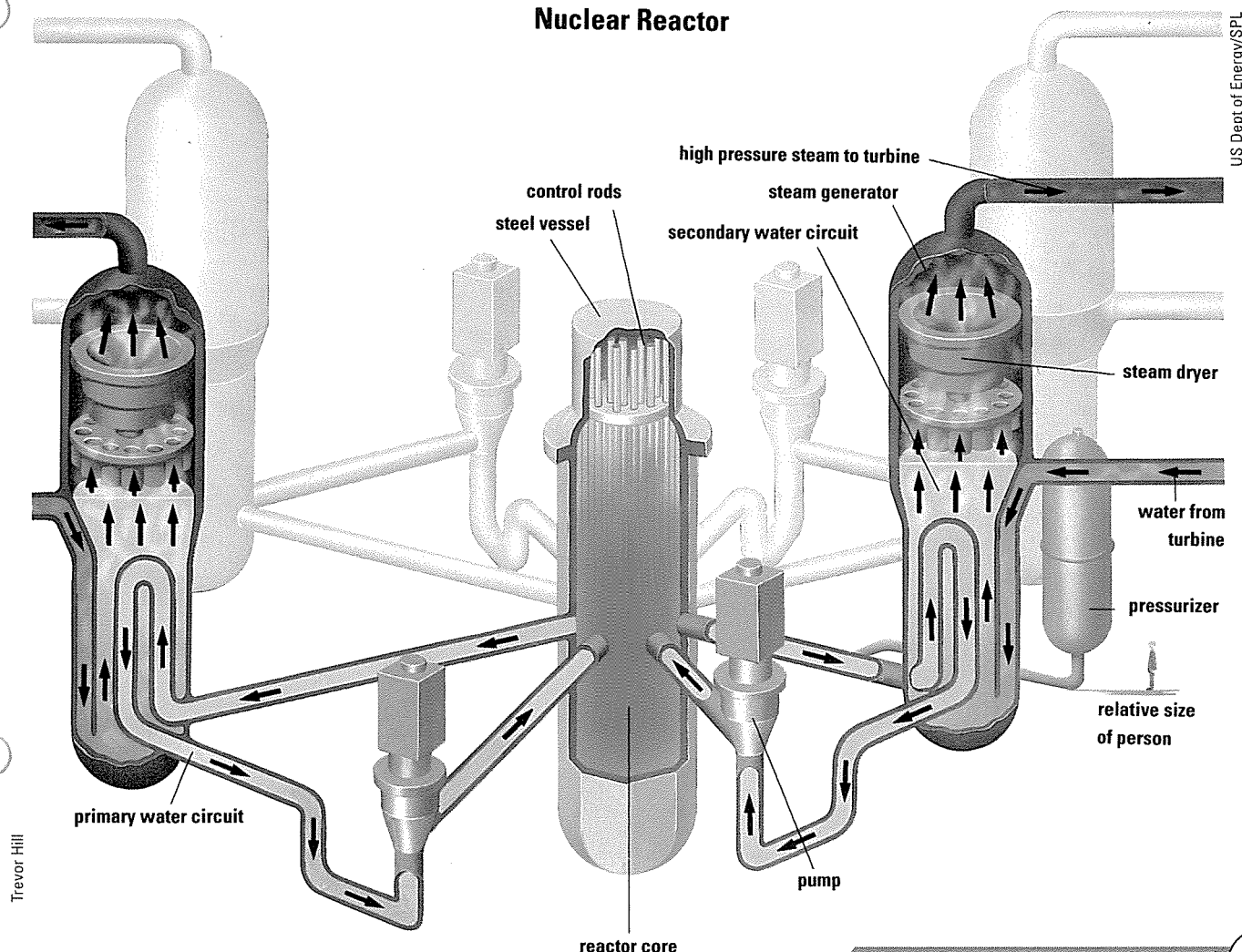
Breeding plutonium

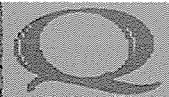
To keep going, a breeder reactor needs a very large number of neutrons because so many are absorbed by U-238 nuclei in the process that 'breeds' plutonium. There must be enough neutrons left over to sustain the chain reaction with U-235. This means using only fast neutrons inside the reactor, since these give rise to a greater number of fresh fast neutrons.

Molten glass containing nuclear waste being poured into a mould. When solid, it is relatively safe for disposal as the glass prevents water leaching out the radioactive materials.



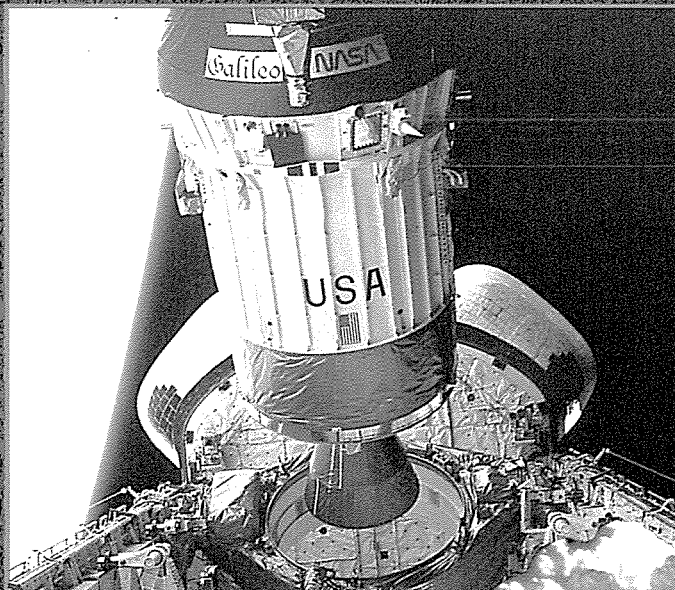
Nuclear Reactor





VIEW

THE MIGHTY ATOM



NASA/SPL

The Galileo probe left the Space Shuttle in October 1989. Nuclear generators power the probe as it continues its six-year journey to the planet Jupiter.

Nuclear radiation affects all living things. It forces cells to mutate genetically, producing new species. The effects are studied in the laboratory.

O. Schmitt/Corbis



TRH Pictures/DOO/USA

A geiger counter being used to check the level of contamination by radioactive materials in a research laboratory.

The H-bomb is powered by nuclear fusion. Energy is released when hydrogen isotopes, deuterium and tritium, join together.



Hank Morgan/SPL

An aircraft carrier powered by two nuclear generators. This ship, USS Nimitz, can stay at sea for up to 13 years without having to refuel.

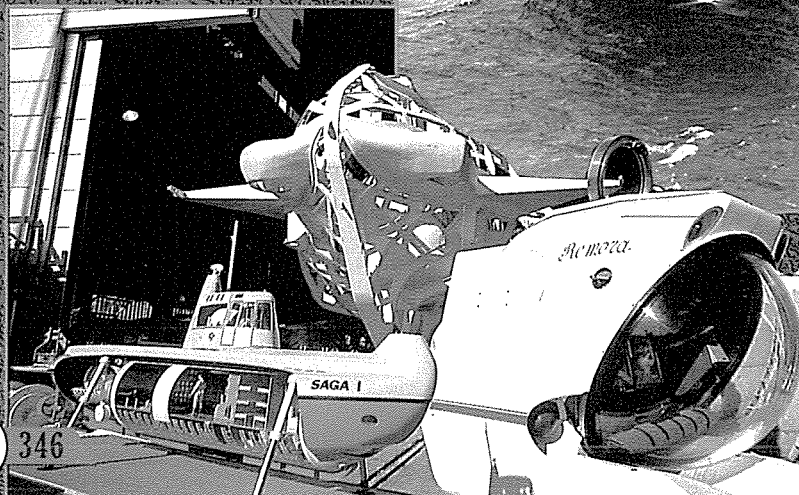
Radioisotope cobalt-60 is the source of gamma rays used to treat this patient for cancer of the spine. Laser beams help aim the radiation at the target area.

TRH Pictures/DOO/USA

Wynn Doherty/SPL



The first nuclear submarine in commercial use was the Saga 1, developed by Henri Delauze (right). The actual vessel is behind the cutaway model.



Rex Features





RESUSCITATION



DEFIBRILLATION



ECG

EMERGENCY



Swift action by ambulance teams can mean the difference between life and death for accident victims. Here, oxygen is administered to the victim of a road accident.

A MAN COLLAPSES ON THE street, gasping for breath and clutching at his chest – the victim of a massive heart attack. Within minutes he might suffer irreversible brain damage and die. But help is on the way. A well-equipped ambulance and crew will keep him alive until he arrives at a hospital emergency room.

No medical emergency is more dramatic or urgent than a sudden heart attack, or cardiac arrest. All at once, a person's heart stops beating properly and the flow of blood to the brain is cut off. The victim loses consciousness and ceases to breathe or show a pulse. Only immediate treatment to restart the heart can then save the individual's life.



Dangerous delay

Even the short delay in getting a heart attack victim to hospital may be too long. For this reason, ambulance crews are trained in two basic meth-

ods of revival. The first is a manual technique known as CPR, or cardiopulmonary resuscitation. This involves the medic breathing into the patient's mouth – the 'kiss of life' – and pressing on the chest repeatedly to get oxygen as quickly as possible to

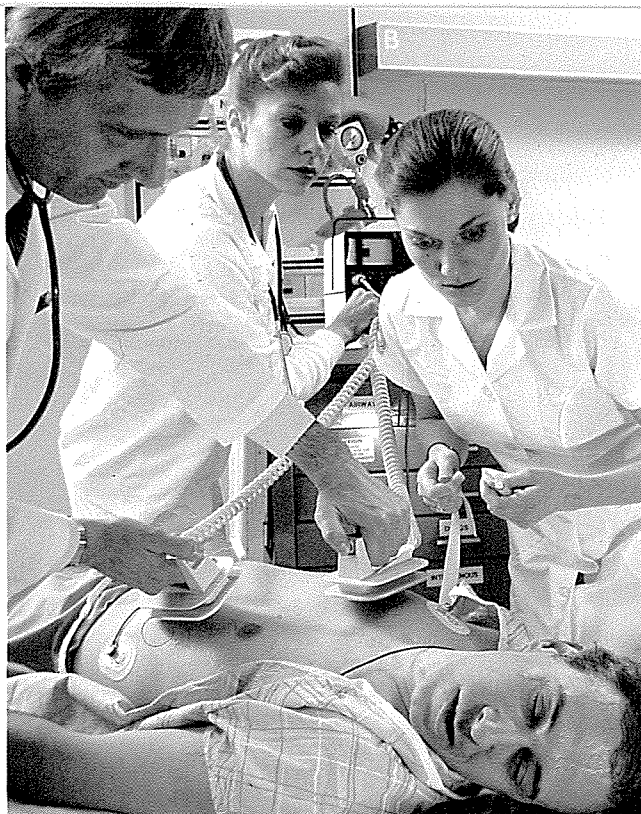
the brain, heart, and other vital organs. Following successful CPR, a special tube is inserted into the trachea, or windpipe, to keep the vital air passage open to the lungs.

If the heart is still not functioning, the emergency crew apply a defibrilla-



Photo: Peter G. Brown/Photo Bank





tor. This consists of two metal plates with insulating handles that can deliver a brief but powerful electric shock across the patient's chest. The sudden shock interrupts the random twitching of the heart muscle and gives the heart a chance to resume its normal electrical activity.



Fatal shock

The difficulty is that many heart attacks occur at home, where no expert is on hand to work an ordinary defibrillator. If not applied properly, these devices will fail to restart the heart – and worse, they can give the operator a fatal shock.

Newly developed automatic defibrillators may soon change the situation, however. The rescuer simply attaches adhesive electrodes to the victim's chest, and the automatic defibrillator does the rest. Pro-

A defibrillator has many different features to help monitor its use.

It shows, for example, whether the paddles have made proper contact with the patient's chest, and the central screen shows the patient's heart rate.

A cardiac arrest patient is given emergency treatment in hospital. The two paddles, or plates, of a defibrillator are applied to his chest. These transmit an electric shock, which will give the heart a chance to start beating normally again.

sends out a series of electrical pulses through fine wires leading to the heart over a 15- to 20-second period.

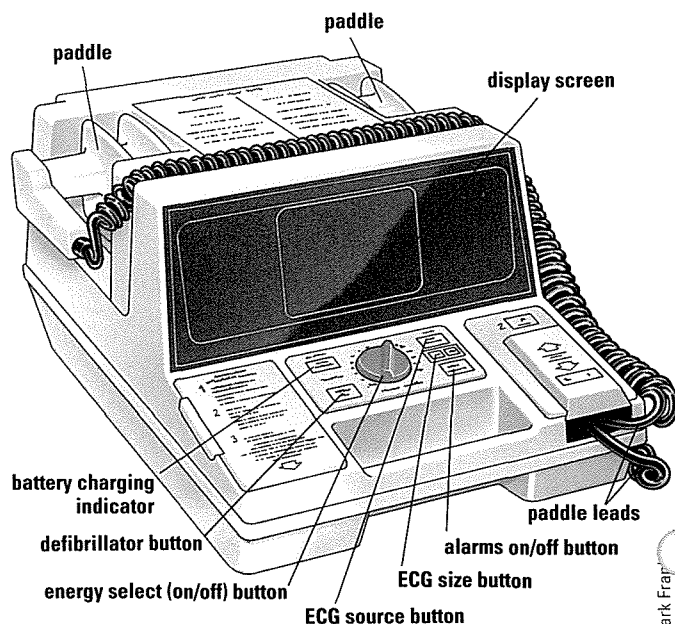


Changing batteries

Since the pulses do not have to pass through the chest wall, they need to have only about one-fifteenth the energy of a normal defibrillator shock. The power source for the implant is a lithium battery that lasts about three years and can be replaced at regular intervals by a minor operation.

Doctors fighting to save the life of a critically ill or injured person need

Defibrillator



Mark Fram

RESUSCITATION

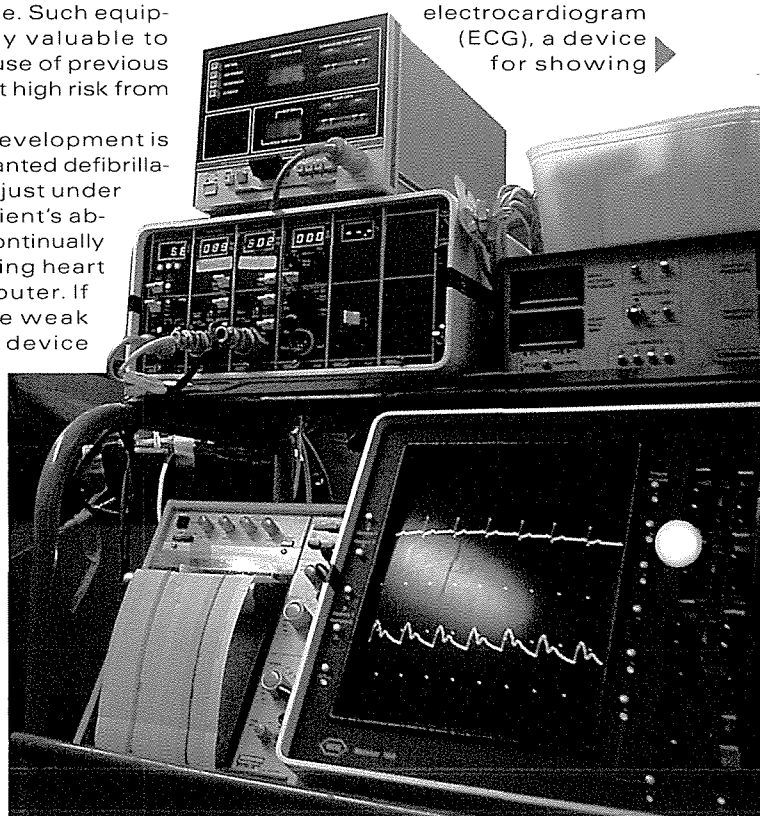
Cardiopulmonary resuscitation, or CPR, is used when someone shows no signs of breathing or having a pulse. First, the head is tilted back to open a clear passage to the lungs. Then, the rescuer pinches the patient's nostrils, seals his mouth over the patient's mouth, and blows. After two breaths, about five seconds apart, the pulse is checked. If there is no pulse, the rescuer thumps the patient's chest with a clenched fist. This simple action can have the same effect as an electric shock starting the heart off again. If this is unsuccessful, the rescuer places the heel of one hand over the patient's breastbone, covers it with the other hand and applies pressure about 15 times in succession. Then the rescuer delivers two more breaths, followed by another set of chest compressions, and so on, until the patient successfully revives.

grammed to detect the condition of the heart, it decides whether to administer a shock, where this should be directed, and how powerful it should be. A synthesized voice or liquid-crystal-display messages help the rescuer to set up the device. Such equipment is especially valuable to people who, because of previous heart trouble, are at high risk from heart attack.

Another new development is the surgically implanted defibrillator. This is placed just under the skin of the patient's abdomen, where it continually monitors the beating heart with a microcomputer. If the beats become weak and irregular, the device

continually to monitor the patient's breathing and heart condition. Instruments that automatically display breathing rate, blood pressure, and heart rate have been available for some time. Also, the electrocardiogram (ECG), a device for showing

In the operating theatre, an electrocardiograph monitors how the patient's heart is working, showing the information on screen and as a print-out. Above the screen are digital read-outs for blood pressure and pulse rate.



the electrical activity of the heart, is a familiar sight in hospital emergency and recovery rooms.

The ECG works by sensing the tiny electrical currents produced by muscles in the heart. These are transmitted to the machine through wires from a dozen electrodes, which are moistened with conductive paste and fixed to the arms, legs and chest. The ECG then amplifies the currents about 3,000 times and traces the pattern of heart waves on a strip of moving paper or a screen.

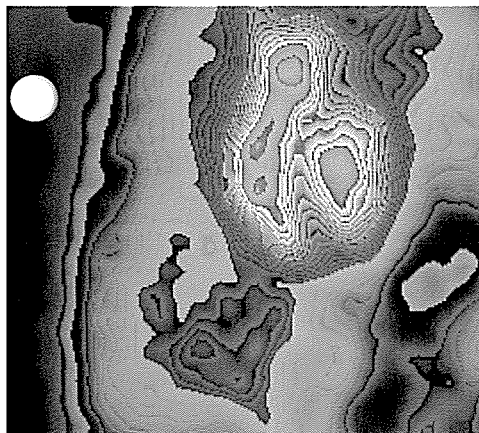


ECG alarm

Patients who are recovering from a heart attack or coronary surgery are connected to an ECG in the recovery room. If the device senses that the heart is behaving abnormally, it instantly sounds an alarm at the nearest nurses' station for emergency help.

One of the latest monitoring devices is the niroscope. It can show within two to three seconds whether the brain is receiving sufficient oxy-

The activity of the human heart can be monitored by the gamma camera. This gamma camera picture shows the heart during diastole, the period between contractions when the heart fills with blood.



Alexander Tsiaras/SPL

gen. Such a warning may be crucial, for example, while the patient is under anaesthetic – starved of oxygen for just three minutes, the brain would be permanently damaged.



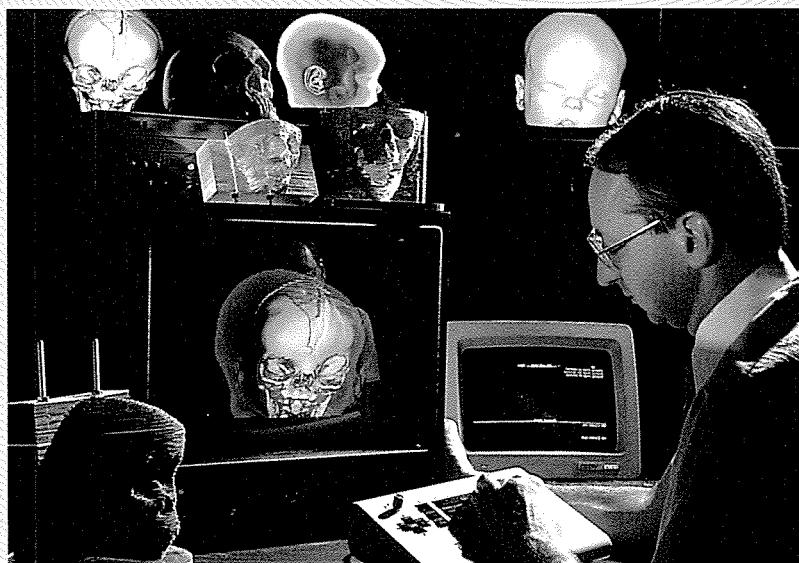
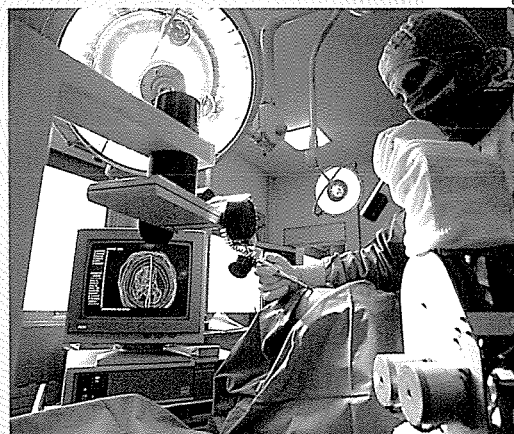
Oxygen starvation

The niroscope works by shining infrared light of different wavelengths through the skull into the brain and measuring how much of that light is reflected back out again. The brain's tissue changes its absorption of infrared light depending on the amount

Nuclear cardiology, involving the gamma camera, is especially useful in checking damage to the heart muscle after an attack and in monitoring blood flow. A single sodium iodide crystal picks up radiation from the heart, and this is then transformed into a picture.

COMPUTERIZED BRAIN SURGERY

Some of the most difficult and delicate surgery of all has to be carried out on the brain. Brain surgeons may soon have access to a computerized system that allows them to see an image of a patient's brain before they operate. This system lets doctors draw their incision on a video picture of the patient's skull, then press a button to see the underlying folds of the brain. Another program allows them to view a slice through the brain at the point exposed to check, for example, whether a tumour they want to remove is underneath. The new computer system uses data collected by a method called magnetic resonance scanning.



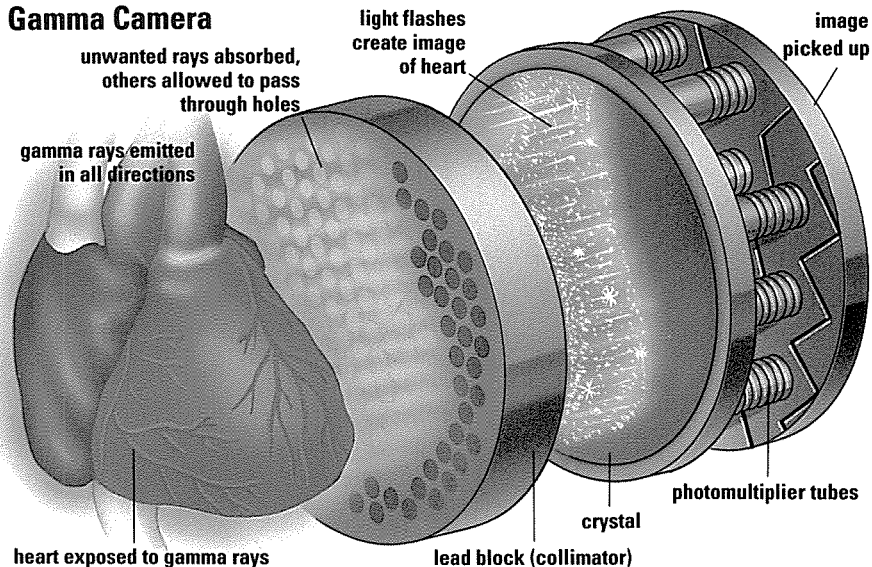
Philippe Plailly/Science Photo Library

of oxygen available to the nerve cells.

Another valuable new monitoring tool is the echocardiogram. This works by recording the echoes of ultrasonic waves – very high-frequency sound waves – from various parts of the heart. The results can show blood clots, faulty valves and other abnormalities of the heart that might otherwise escape detection.

The most recent development of this technique involves the use of a tiny sound transmitter that provides an even clearer image of the beating heart. The device is located at the tip of a long, flexible probe that is passed down the throat of the anaesthetized patient. By altering the angle and position of the probe, the doctor can accurately direct ultrasound waves at

Gamma Camera



Mark Franklin





Military field hospitals are vital to help wounded troops survive. Emergency surgery performed by combat-trained surgeons directly after a soldier has been injured can make the difference between life and death.

Other identification methods include mass spectrometry. Using this method, the chemical formula of the poison is worked out by measuring the numbers of different atoms in a blood sample.

Washing the stomach

Treatment then follows immediately. One of the simplest procedures is gastric lavage, or washing out of the stomach with warm water. However, this does not usually work if over four hours have passed since the poison



S Fraser/Dept of Child Health, RVI, Newcastle/SPL

a particular portion of the heart. An image of that section of beating muscle then appears on a video screen.

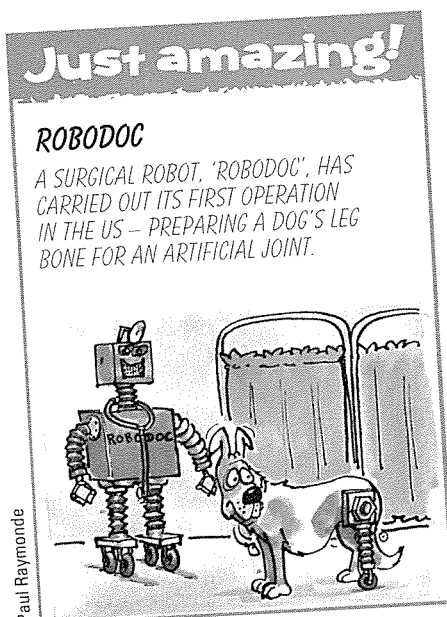
Accidental death

While some emergencies are caused by natural disorders of the body, others come about through accidents. Poisoning, for instance, is one of the commonest causes of accidental death, along with car accidents, drowning and burns. Increasingly, though, poison victims are being saved by new, faster methods of identifying the chemicals swallowed and then removing them.

A doctor examines a nine-day-old baby, kept alive on a ventilator. After premature delivery by caesarian section, the baby was given an emergency operation on its small intestine.



A pacemaker, or pulse generator, is implanted in a patient's chest. This is connected to a lead threaded through a vein into the heart. The pacemaker then sends an electrical impulse down the lead to regulate the heartbeat.



Paul Raymonde

John Watney Photo Library

The treatment for poisoning depends on the substance involved. If this is unknown – as is often the case with young children – then tests have first to be carried out. The latest of these is EMIT (enzyme multiplied immunoassay technique). This relies on the fact that chemicals called antibodies will attach themselves to molecules of a particular drug.

was swallowed. Then, a more advanced technique such as haemoperfusion may be used instead. Haemoperfusion involves passing the patient's blood through a column containing charcoal coated with a substance called acrylic hydrogel. During the process, the charcoal forms chemical bonds with the poison and so removes it from the blood.



TO THE ENDS OF THE EARTH



Modern-day polar explorers use skidoos and other mechanical means to get about on the ice cap. But extreme cold is still a problem. Water vapour given off by the body can freeze inside clothes (right), drastically cutting their insulating properties.

EXPEDITIONS TO THE POLES and to the summits of high mountains face incredible hardships. Yet their success is made more likely by an array of modern technology.

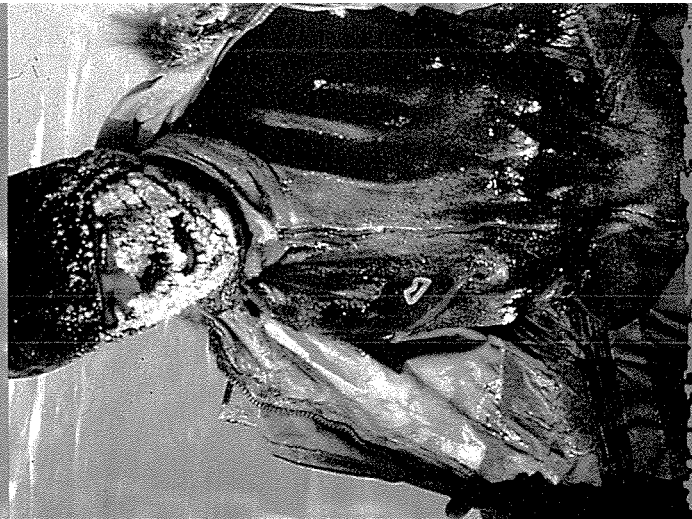
The harshest frontiers on Earth are the frozen regions north of the Arctic Circle – an imaginary line at 66° 31' N – and regions of the south polar continent of Antarctica. Here, the temperature can plunge as low as -70°C while fierce winds lash bare

skin with icy snowflakes. Naked, exposed to -40°C temperatures and 44 km/h winds – conditions common in the Arctic winter – a man or woman would have a life expectancy of about 15 minutes.



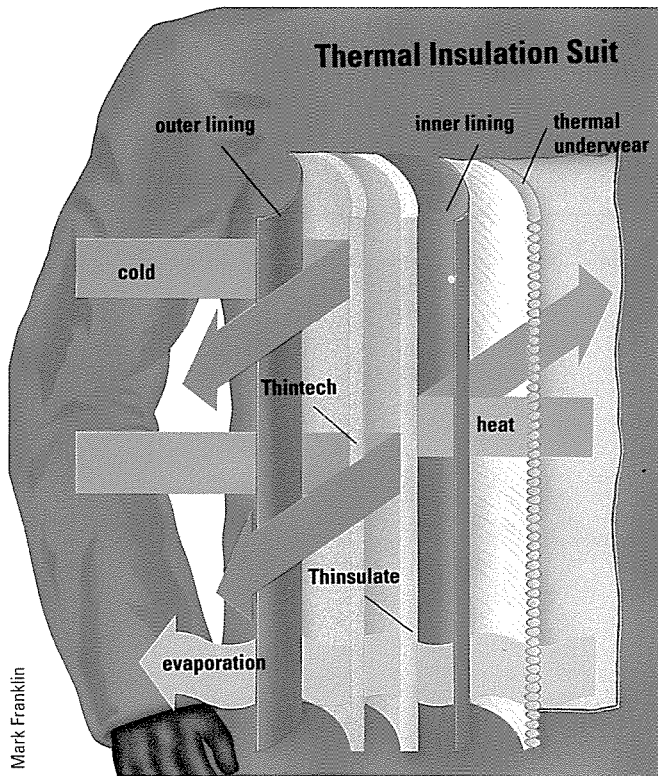
Bare flesh

Polar survival depends on retaining body heat. At -35°C bare flesh freezes within about one minute. Keeping warm is made especially difficult by windchill – when a strong



Westward Ho Adventure Holidays Ltd





Mark Franklin

wind brings the effective temperature down to dangerous levels. A low air temperature combined with gale-force winds can quickly lead to two potentially threatening conditions. The first is frostbite, which starts with a loss of feeling in the fingertips, toes and parts of the face. The affected

Hot food and a warm sleeping bag are vital, even when stopping to check the course. Getting lost or cold means just one thing – death.

Thermal underwear traps an insulating layer of air in thin ridges. Outer layers of Thinsulate trap air in a boundary layer against the fibres. Thintech keeps out wind and water.

An old-fashioned sled and huskies still come in useful in polar regions. Although modern snowmobiles can travel efficiently across the icy wastes, engines can freeze up.

air spaces, causing the clothing to lose warmth.

For this reason, polar travellers today prefer to wear synthetic clothing. Composed of polyester or polyolefin fibres, these absorb almost no water but instead carry it away from the skin to the outer surface of the clothing. Synthetics, such as Du Pont's Hillofil and 3M's Thinsulate, also have the advantage of retaining 'loft'. That is, they continue to trap air when wet, and dry rapidly even in freezing temperatures.



Underwear

Layered clothing provides far better insulation than just one or two heavy garments. A carefully chosen combination of underwear, pants, vest sweater, parka and mittens keeps

Mark Franklin



Sverre Arseth/Royal Geographical Society



Roger Mear/Royal Geographical Society

captured moisture to a minimum while trapping as much warm air as possible. Finally, a woollen hat plus fur-lined hood is indispensable. Below -40°C , more than half of a person's body heat could escape from an uncovered head.



Danger to life

Because of the danger to life posed by extreme cold, shelter is second only to first aid in a survival situation in mountains and cold regions. Polar tents are generally small so there is less volume to heat and of a low, curved profile to deflect strong winds. Inside, high loft sleeping bags of down, or down mixed with polyester,

WORST WEATHER

With a summit at 1,916 metres, Mount Washington in New Hampshire is dwarfed by 8,840-metre-high Mount Everest. Yet, it is exposed to the powerful prevailing winds in this region and also lies at the meeting point of three storm tracks. As a result, Mount Washington is home to some of the world's most severe weather. Winds reach hurricane force about every third day, and the highest straight-line wind speed on Earth was recorded here at 372 km/h. Many who have attempted to climb it improperly equipped have met with frostbite, hypothermia and death.

skin turns red, then white and finally grey as the blood circulation stops.

Even more deadly is hypothermia, the first symptoms of which are shivering and drowsiness. Hypothermia happens when the body's core, or internal, temperature begins to fall. If it drops even two degrees below normal, the victim may die.

Proper clothing is essential. It has

to insulate a person's body by trapping pockets of warm air next to the skin. This calls for a fabric whose microscopic fibres have a relatively large amount of surface area, in order to trap more air.

In the past, down from young birds was a popular insulating material. But as down becomes wet, through perspiration, it mats. This squashes the



help provide personal warmth. Some expeditions, however, travel without sleeping bags to save weight. By relying on their insulated polar suits to keep them warm by night as well as by day, team members are also better equipped to survive if an ice crack opens up underneath a tent and they fall down it.

All Terrain Cycle

Getting around on the polar ice can be achieved in several ways: on foot using skis, by dog sled, by snowmobile, or by All Terrain Cycle (ATC). An ATC is a motorized tricycle with balloon tyres, which help absorb bumps and stop the vehicle from sinking into soft ground or slipping on ice.

To travel quickly and safely to remote parts of the Arctic or Antarctic, small aircraft are most useful. They can also carry food, baggage and scientific equipment – everything the scientific teams need to survive and work – in large quantities to polar re-

other hand, have the ability to land on even smaller patches of ground but are more limited in their range.

Travelling by foot is particularly hazardous in the Arctic, where leads, or open stretches of near-freezing water, can suddenly open up in the pack ice.

In spite of the low temperatures, winter is the best time to make good progress. Even then, however, there are obstacles called pressure ridges that form when massive blocks of

still last until the end of the journey.

The average distance from the tree line of the Arctic to the North Pole is 2,300 km. In all that distance, there is little chance of finding anyone who can help if an expedition runs into difficulties. As a result, radio contact is a vital communications link.

Search and rescue

In the Canadian Arctic, for instance, explorers are required to contact a base station twice a day, at 7 am and



Beedell/Sipa/Rex Features

The Antarctic is now the home of vital environmental research. This balloon is being sent up to sample the ozone layer. A hole in the ozone layer over the South Pole is causing great concern.

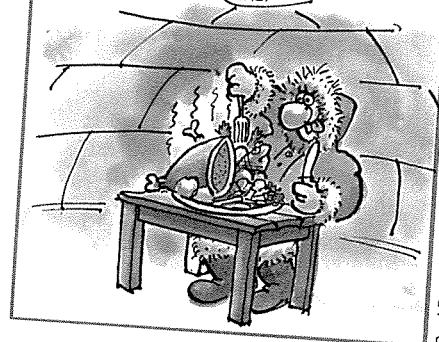
7 pm. Failure to radio in three times in succession leads to a search and rescue plane being sent out.

As well as normal radio transmissions, polar travellers can use orbiting satellites to fix their position or send out an S.O.S. message. Some expeditions, however, choose not to employ modern technology but to rely instead upon the simpler technique – navigation by the Sun and stars.

Just amazing!

FATTY FOODS

POLAR TRAVELLERS BURN UP SO MUCH ENERGY THAT THEY MUST EAT A DAILY, FAT-LADEN DIET OF ABOUT 7,000 CALORIES – MORE THAN DOUBLE THE AVERAGE MAN'S INTAKE.



Paul Raymond

Light planes used in polar regions have their wheels replaced with skis so they can land on soft snow. This plane is landing at Palmer Station, on Grahamland Peninsular, Antarctica.

search stations or members of trans-polar expeditionary teams who are on the ground.

Short take off

The De Havilland Twin Otter, a twin-propeller plane that can land or take off on skis or balloon tyres in distances as short as 200 metres, is especially popular. Helicopters, on the

sea-ice collide and crumple. Together with the unpredictable and hostile weather, this means that expeditions often find themselves running behind schedule – and, worse, begin running out of food.

Whiteout

One of the most feared of polar events is the whiteout, caused by a heavy blizzard or low, dense mist. When this happens, the horizon vanishes and every direction appears to be exactly the same.

The only course of action is to hastily set up tents and wait out the storm, hoping that food rations will



Gamma/Frank Spooner Pictures



This 'boy in a bubble' only survives because he is completely sealed off from the world. He has no immune system to fight off germs so the smallest cough or the slightest cut in the outside world could kill.

Associated Press

A broken leg half way up a mountain can be fatal. This survivor is lucky. The local Lochbar mountain rescue team is evacuating him down the 550-m cliff face of Ben Nevis in Scotland, the highest peak in the British Isles.



An armed hijacker holds a gun on TWA pilot John Testrake on a hijacked plane in Beirut in June 1985 after demands had been shouted to the authorities. Testrake survived. Many hostages have not been so lucky.

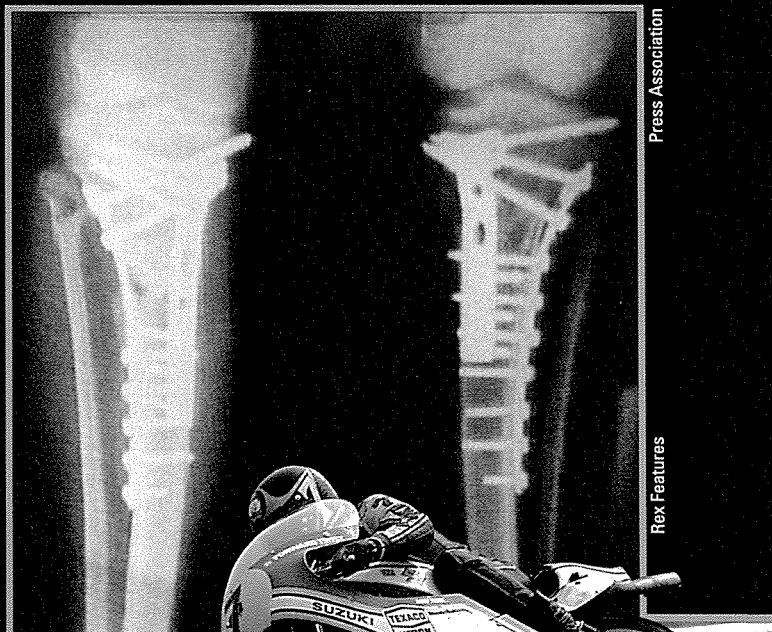
John Cleare/Mountain Camera

Gamma/Frank Spooner Pictures



An earthquake destroyed 50 per cent of the Algerian city of El Asnam in 1980, killing 20,000. For weeks after, survivors were being pulled from wrecked buildings.

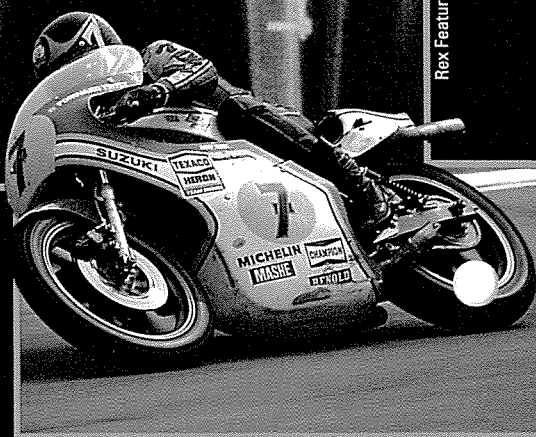
Not many people have been attacked by a Great White Shark and lived to tell the tale. This survivor still bears the marks where the fish held him in its mouth.



Press Association

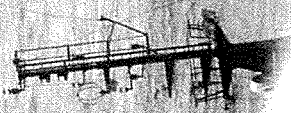
Rex Features

World motorcycle champion Barry Sheene crashed numerous times. His legs (above) have been bolted back together using stainless steel 'scaffolding'.



Q HEAT LOSS
Q RADIO BEACONS
Q WATER PRESSURE

THE CRUEL SEA



The sea is a hostile environment. The shipwrecked face death by drowning, exposure and dehydration.

The great barracuda is the most vicious of that species. It has long canine teeth for seizing its prey and smaller razor-sharp teeth for tearing its victim to shreds.

WHEN MAN CHALLENGES THE sea he faces a hostile and sometimes deadly environment. Survival depends on a variety of specialized equipment and techniques.

Victims of a shipwreck are confronted with several immediate dangers. These include loss of body heat in cold water, drowning through exhaustion or rough seas, and possible attack by sharks. Some basic know-how and emergency gear, however, can mean the difference between life and death.

Being suddenly plunged, or

spending an lengthy of time in cold water (below 22°C) can lead to immersion hypothermia – a major cause of death in water-related accidents. An object in water loses heat about 24 times faster than in air. In the chilly waters of the North Atlantic, for instance, a person's survival time might be measured in minutes.

Exposure suit

The important thing is to prevent as much heat as possible from leaving the surface of the skin. This can be done by putting on an exposure suit, a head-to-toe, international-orange

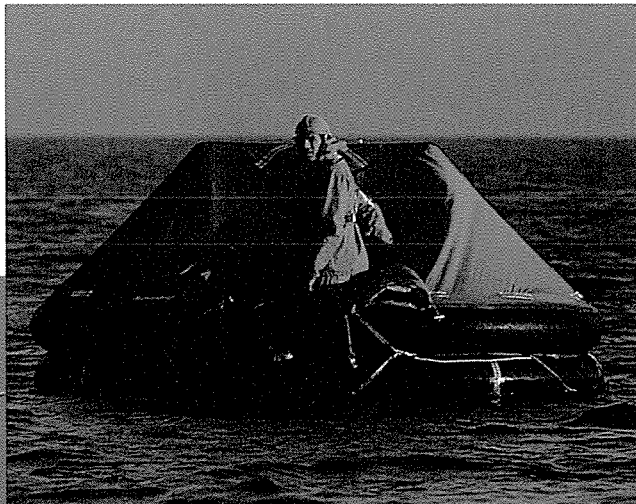
Linda Pikin/Planet Earth Pictures



suit that provides buoyancy in the water and insulation against the cold.

A different type of survival suit – a one-piece, zip-up, dry suit, specially developed for use on oil rigs – gives a survival time of 12-15 hours in the North Sea in winter. Movement of any kind has to be restricted to a minimum. If several survivors are in the water, they should huddle together.

This life raft, designed to inflate automatically, has a built-in shelter to protect against spray, breaking waves and wind exposure. Survivors should be secured to the life raft.



Rex Features



enough to cause severe pain, swelling and – worst of all – panic in the victim. A swimmer may then get cramp and lose energy, which may result in drowning. Other stinging marine creatures, like the stonefish and sea urchin, are only a real danger to those walking barefoot on warm, sandy sea beds.



Flotation device

For long periods in the water, some kind of flotation device is essential. A personal flotation device (PFD) is to open ocean survival what a warm sleeping bag is to cold regions survival: a life saver. The most effective

locking arms and legs, to expose less surface area to the cold sea.

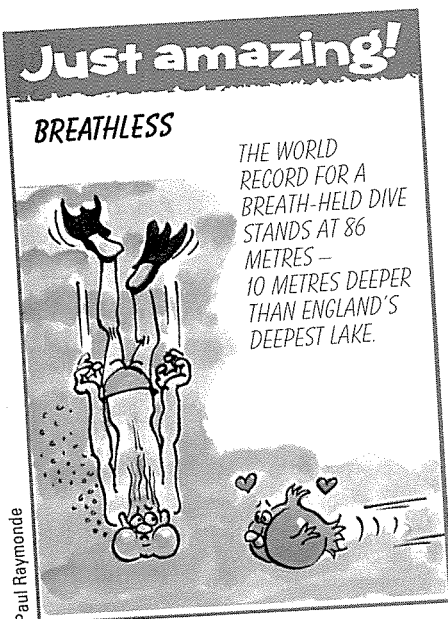
Alone, a person would be best advised to use HELP, the Heat Escape Lessening Posture. The aim of this is to protect the body's high heat-loss areas – the head, sides of the torso, and groin. It involves keeping your head out of the water, drawing your arms close to your sides and tucking up your legs to your chest.

Despite their ferocious appearance

Most lifeboat services operate a cover, search and rescue operation in inshore areas – usually within 50 km of the coast. They are assisted by a helicopter rescue service that can winch survivors to safety in seas that are too rough for lifeboats to navigate. Packed lifeboats (right) on a ferry.



Limier/Jerrican



Paul Raymonde

and reputation, sharks are more likely to be curious about someone in the water than dangerous. They are especially attracted by blood, splashing movements and bright clothing. However, a sharp poke on the snout is usually enough to send one away if it comes too close. Two-metre-long barracudas can also pose a threat in shallow waters, especially around schools of small fish.

With its long, stinging tentacles, the Portuguese man-of-war jellyfish is to be avoided at all costs. One sting is

tive kind is an inflatable jacket worn around the neck and upper body that is filled with air either by blowing into a valve or by an attached gas canister. This keeps the head above the waves, face back, so that even if the wearer is exhausted or unconscious he or she can continue to breathe.

Better still is a life raft. These are inflated by pressurized gas cylinders and contain a range of survival gear. The onboard kit consists of first aid materials, signalling devices, water, food and navigational equipment.



A Diver Propulsion Vehicle (DPV) designed to minimize dive time. It can travel at speeds of up to six knots, and in the event of a mechanical malfunction, the faulty half of the system can be jettisoned, allowing the diver to return to base on the spare.

strapped to the diver's back with a pressure gauge to show how much compressed air remains inside them. At the surface, a single tank will last about 56 minutes. But at greater depths, more and more air is required

FIGHTING THE BENDS

Under high pressure, a diver breathes more air than normal and the extra nitrogen in the air is absorbed into the diver's body. If the diver surfaces too quickly, nitrogen bubbles form in his body causing agonizing pains in bones, joints and muscles. Because of the writhing it causes, this condition is known as the bends. The only way to cure the bends is to quickly put the diver in a decompression chamber. Air is pumped into this at high pressure and then released very slowly. This gives the dissolved nitrogen in the diver's body time to escape without bubbling.

The inflation mechanism works manually by pulling the ring handle at the base of the unit. This, in a series of stages, pushes the piercer to puncture the CO₂ bottle, releasing the gas to inflate the life-jacket.

Mark Franklin

Every attempt is made before abandoning ship to radio the position of the vessel to the coast guard. But help, in the form of another ship or a helicopter, may be several hours or even days in coming. It is vital, then, that survivors can signal their whereabouts from several kilometres away.

Signalling

During the day, orange smoke canisters, sea dye markers, and sun-reflecting mirrors are especially useful in attracting attention. At night, rockets, red hand-held flares or red

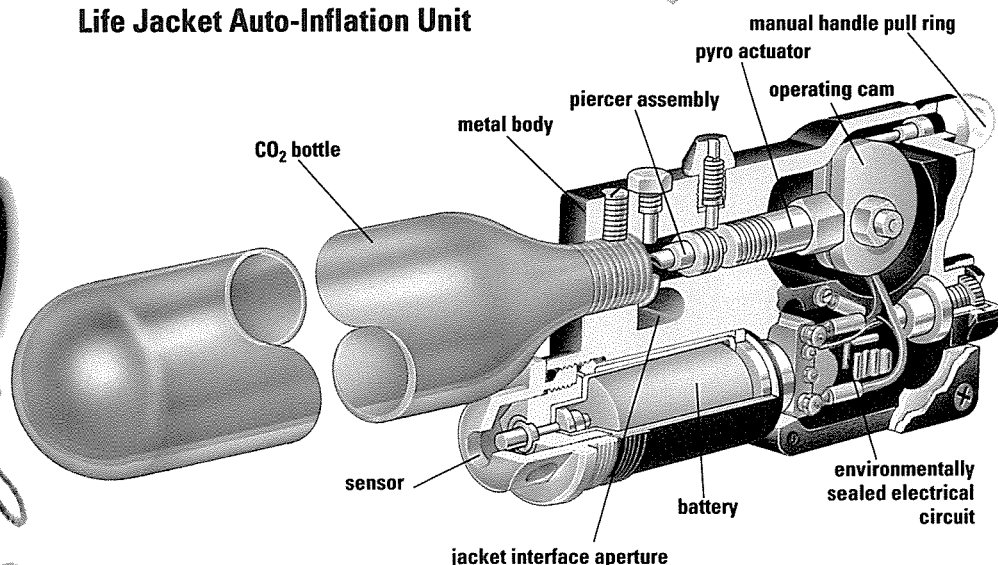
parachute flares may be used instead.

Today, the most effective signalling systems are emergency locator transmitters (ELTs) and emergency position indicating radio beacons (EPIRBs). These small, lightweight beacons are shock-resistant and begin transmitting automatically when they come into contact with water. The signal, which is broadcast continuously on emergency distress frequencies for at least 48 hours, may be picked up by passing aircraft, ships or a rescue satellite system. If received by satellite, the message is relayed to an international network of ground stations and then to a rescue control centre.

Surviving for long periods under

A water-activated battery that energizes an electrical circuit ensures that an unconscious pilot or crew member will be supported by the life-jacket.

Life Jacket Auto-Inflation Unit



water poses even more severe problems. Deep-sea divers not only carry their own air supply with them, they also need protection from the build-up of pressure with increasing depth.

An aqualung or SCUBA (Self Contained Underwater Breathing Apparatus) ensures that a diver can breathe normally at all times. Between one and three 7-litre air tanks are

to counterbalance the increasing water pressure. So, at a depth of 10 metres, one tank would only last about 28 minutes, while at 20 metres down, the supply would run out in just over 18 minutes.

The pressure in the air tanks is often over 150 times normal atmospheric pressure. But the pressure of air the diver actually breathes has to be the same as the surrounding water pressure. The air must always come



SENDING AN SOS

Hand stars, carried aboard lifeboats and other small craft, fire two red stars with an interval of three to five seconds between them. The stars reach a height of about 45 metres and burn for roughly five seconds. For signalling over greater distances, parachute flares are used. These are rockets, fired from a plastic launching tube, that open and release a red flare beneath a four-string parachute. The light burns for over 40 seconds, as it drifts down at a rate of 4.6 metres per second, and can be seen from 45 kilometres away on a clear night. During the day, fireworks are difficult to see, therefore orange-coloured smoke flares may be used instead.

in at the precise rate the diver needs. Both these requirements are handled by the demand regulator.

By breathing in, the diver automatically operates a spring that opens the inlet valve. This lets air flow in from the tank. When he breathes out, the supply through the inlet valve is closed off, and the used air escapes through the outlet valve.



Air underwater

The greatest danger is if the air supply starts to run out. To signal this, some aqualungs have a kind of early warning. When there is only enough air to let the diver return to the surface safely, the air flow is restricted, making breathing more difficult. By pulling a by-pass lever the diver can restore the normal supply, but he knows he must come back up immediately.

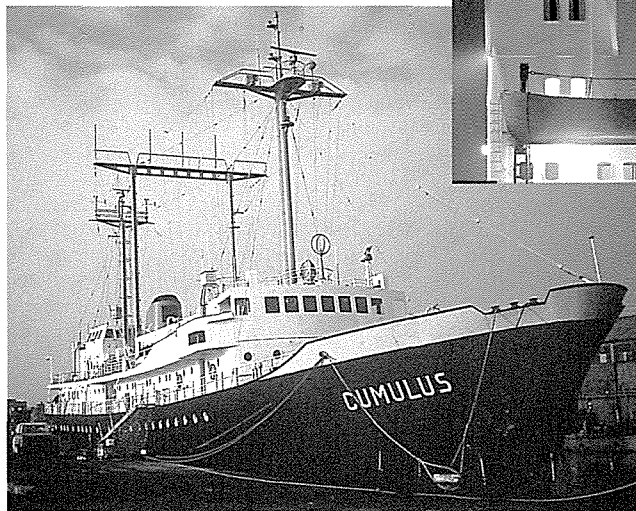
SCUBA gear can be used down to

depths of about 60 metres. For thermal insulation, the diver wears a wet suit made of 5-millimetre neoprene rubber. This traps a thin layer of water next to the diver's body. Since this layer, warmed by the diver's body heat, cannot escape, it acts as a blanket against the cold of the sea.



Hard suit

For survival at greater depths, a hard suit is essential. This completely surrounds a diver like a massive, outer skeleton. One kind of hard suit, known as the Type IV JIM, is made from glass-reinforced plastic with a clear dome of plastic over the head. The



A data-gathering ship operated by the Meteorological Office, collects such information as wind speed and direction. Visible on the supertanker (above) is its satellite-receiving equipment – the white dome.

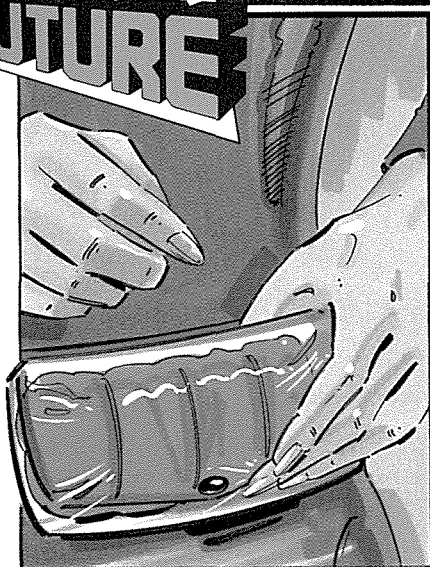
D Parker/Gotaas-Larsen/SPL

diver can be lowered safely to depths of up to 610 metres for periods of up to six hours. Further, because the air inside JIM remains at normal atmospheric pressure, there is no need to decompress on the way up.

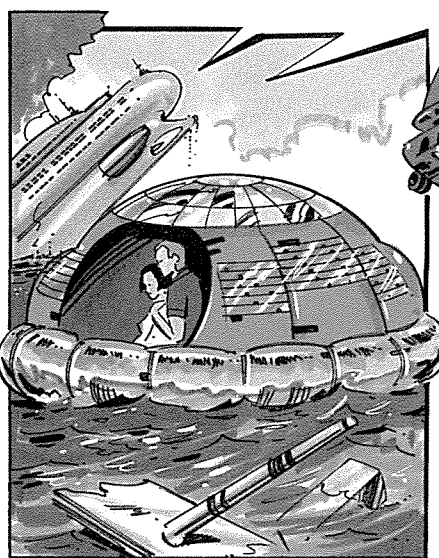
Even deeper dives have to be

made using specially-reinforced vessels called submersibles. A few of these are able to descend to the bottom of even the deepest ocean trenches, about 11 kilometres down, and they may be either manned or operated by remote control.

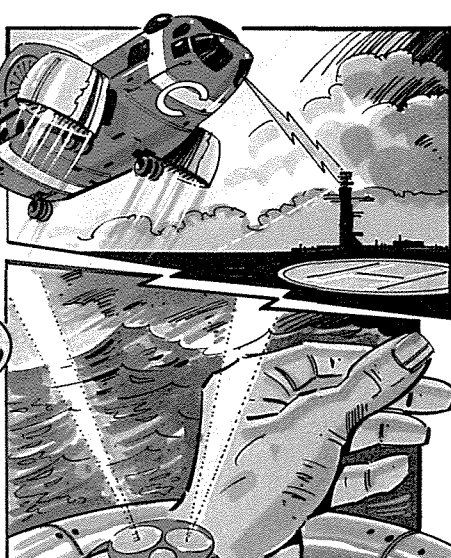
INTO THE FUTURE



▲ Waist pouches will contain inflatable lifeboats equipped with collapsible umbrella structures made of photovoltaic cells that harness energy from the sun.



▲ The solar energy will provide power for the lifeboat, warmth to prevent exposure, and the means to desalinate water, while the canopy will act as a heliograph.



▲ Each passenger will wear a signalling device attached to a wrist band, capable of transmitting signals in all atmospheric conditions and over infinite distances.

POCKET SURVIVAL

Joe Lawrence



OPTICAL PRINTERS

GLASS SHOTS

BLUE BACKING

MOVING PICTURES

Memphis Belle, the film about a B-17 bomber crew in World War II, has a running time of 146 minutes – a total of over 210,000 individual frames of film.

THE MAGIC OF THE MOVIES is based on a fundamental illusion. The pictures themselves do not move at all – the movement is created by a series of stills produced by the film camera.

A movie camera works much like a modern self-wind camera – if you keep the button pressed down. The film is wound through the camera while the shutter continues to click.

Steven Spielberg, the famous director, stands on the set of *Empire of the Sun*, behind a 35mm camera – the standard camera used for feature films.



Kobal Collection

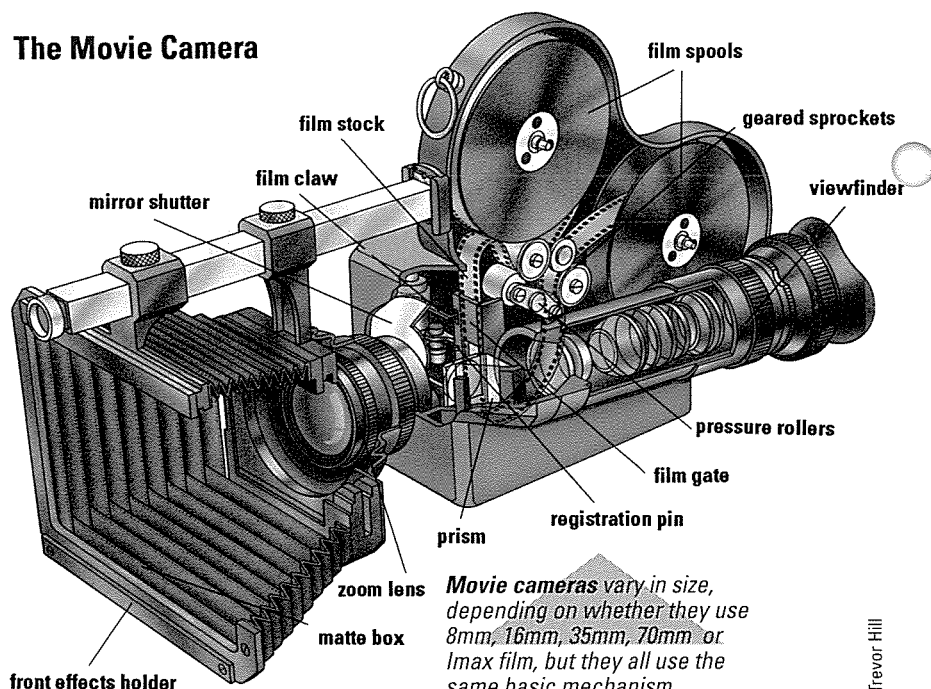


In a movie camera though, the film is transported past the shutter, which fires at a very precise speed, set at 24 frames per second.

The film is pulled past the lens by a device called a claw. This is an L-shaped piece of metal that catches the sprocket holes down the side of the film and pulls them through the 'gate' – two flat pieces of metal that hold the film in position behind the lens. In the gate there is a registration pin. It sits in a sprocket hole to ensure that the film is in exactly the same position for each frame.

The shutter, which lies between

The Movie Camera



Movie cameras vary in size, depending on whether they use 8mm, 16mm, 35mm, 70mm or Imax film, but they all use the same basic mechanism.

Trevor Hill



Picture stability during aerial filming is achieved by isolating the camera from the vibration of the aircraft within two gyroscopic mounts.

A hydraulic platform, operated either directly or remotely by a 'grip', allows a wide range of camera movements and a large variety of different angles.

still used in the cinema rather than video tape because it gives much better quality.

An optical printer is used to create optical effects such as fades – where the picture slowly turns black – or cross-fades – where one scene slowly dissolves into another. In this case, two separate scenes are running simultaneously. One is reflected from a half-silvered mirror, which superim-



ZEFA

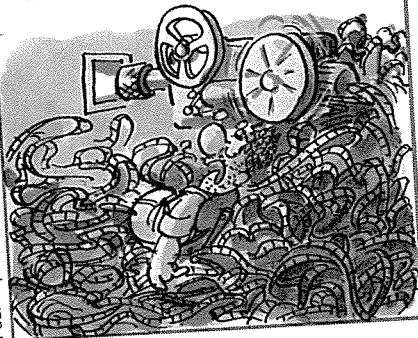
poses it on the other scene. The result is recorded on a third reel of film.

Animated models can be incorporated in real footage, such as when real actors seem to fight with a dinosaur. The dinosaur is a model. It is made to move like a cartoon, stopping the camera after each shot, moving the model slightly, then taking another shot. The real actor is shot

Just amazing!

MARATHON MOVIE

THE LONGEST FILM IN THE WORLD WAS PREMIERED IN CHICAGO IN JANUARY 1987. CALLED 'THE CURE FOR INSOMNIA', IT LASTED 85 HOURS. THAT'S 7,344,000 FRAMES!



Paul Raymonde



Editing with ease

The film and the sound track can be transferred to video, along with their time code – allowing it to be edited easily in a TV editing suite. This way it can be manipulated endlessly without – as used to happen – cutting the film up and splicing it back together.

Once the video has been edited into its final form, the time codes can be used to relocate the original film negative and sound-track tape. Film is



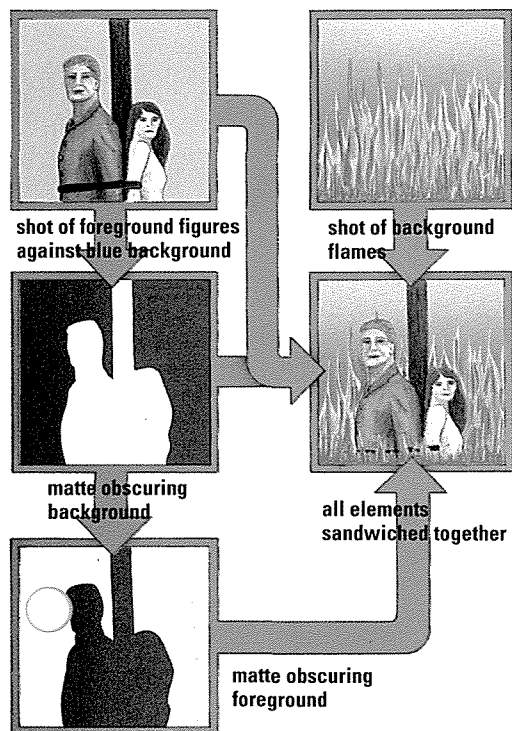
separately and the two shoots married in the optical printer.

One of the most common special effects is the glass shot, in which features of a landscape or building are altered by painting on a sheet of glass fixed in front of the camera. This can add a castle on a hill, or remove a modern building from a scene used in a historical movie.

Another traditional technique is the matte shot. In its simplest form, a card called a matte is positioned in front of the camera, obscuring part of the



Video editing suites enable film makers to edit and manipulate the filmed image in almost any way they wish by the press of a button. All television commercial, pop video and multi-layering effects are done like this.



The travelling matte process allows the director to place actors in any setting. By filming the foreground and background separately he or she can safely put them in seemingly life-threatening situations.

optical printer, it is possible to create a 'travelling matte' which is used, for example, to show Superman in flight. In this case, the matte is not a fixed shape but moves – or travels – with the action.

One way to do this is to create a separate mask and matte for each frame, by hand. This is a very laborious process similar to animating cartoons, but is extremely effective.

Flying through the air

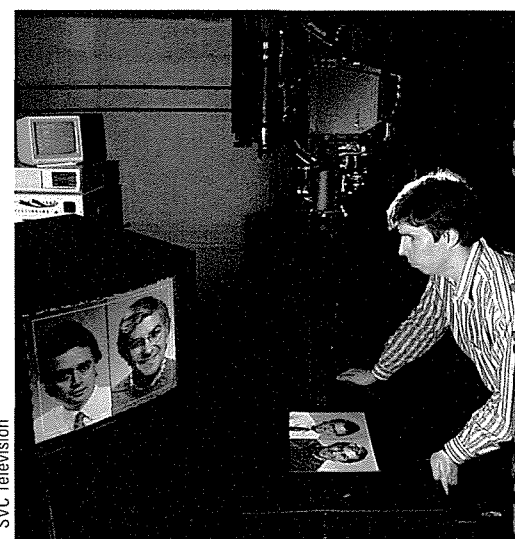
A quicker and cheaper way of doing this is to use the blue backing system. Superman in flight, say, is filmed against a blue background. This is either a blue backcloth or a translucent blue screen lit from behind. The aim is to create a background that exposes only the blue sensitive layer of the film. The blue background must be a different shade to any other blues in the frame. In *Superman*, his costume is always a darker blue than the light blue background in the frame.

That way a blue separation of the film can be made. The positive shows the blue background as a black mask. The negative shows the flying figures as a black matte. The mask and matte perfectly match the flying figure, and when they are run through an optical

printer with the film of Superman flying and the background film showing the city below, Superman really appears to be flying.

Once the film has emerged from the optical printer, the sound track is

Video rostrum cameras are used to overlay an image, like a caption, on to a television picture. The addition is filmed and then superimposed.

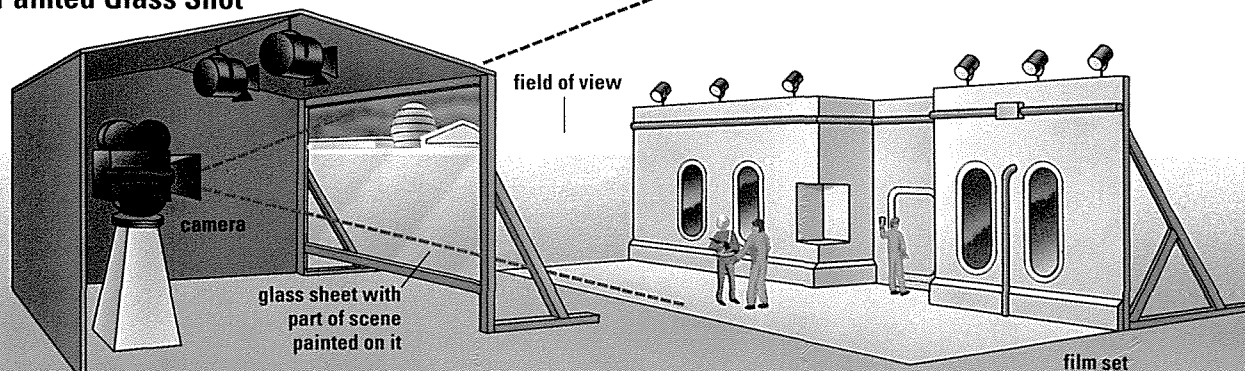


frame. After the film has been run, it is rewind. Then the remaining part of the frame is obscured with a matching card – the mask – and the film is run through the camera again. The resulting double exposure marries together two separate scenes.

Using this technique along with an

A glass shot combines a painting on a sheet of glass with the dramatic action to modify a building, background or some other aspect of the scene.

Painted Glass Shot



Mark Franklin



Temp Sport/Split Second



J.F. Lamour, Olympic fencing champion, remains still as his foil moves. The weapon is held open and the tiny tip on the end of his weapon and remains open while a flash illuminates Lamour.

Flashing-light stroboscopes can illuminate a fast-moving subject at timed intervals along its course. As the shutter is held open, each frozen image is recorded on the same frame of film.

Optical beams help to capture high-velocity subjects. The party popper is suspended in mid-air as the beam and the flash for an exposure of 1/1000 microsecond.

Jonathan Watts/Science Photo Library



Sonic triggers can be used to capture the moment that a balloon bursts. Here, balloon powder inside the balloon holds the balloon's shape as the rubber rips around it.

Jonathan Watts/Science Photo Library



Split Second

Tony Stone Photo Library, London

Shutter speeds of 1/1000 second are fast enough to freeze subjects like athletes and women, making them appear motionless or suspended in air.

A leopard frog takes just 1/10 second to extend its legs, reaching a maximum speed of 96 km/h. A fast shutter speed froze this one in mid-air.

Stephen Dalton/Oxford Scientific Films

Surface tension, drawing the water into droplets, can be observed using high-speed photography. A slow shutter speed would see the arc as a continuous stream of water.



Jonathan Watts/Science Photo Library

FIBRE OPTICS

FAX MACHINES

VIDEO PHONES

COMMUNICATIONS

TELEPHONE LINES

The microwave link is vital to modern communications. Telephone calls, computer data and TV pictures can be relayed the length of the country instantaneously.

The videophone is a product of the future. The caller can see who he or she is speaking to. But it will not be practical until fibre-optic cables are installed.

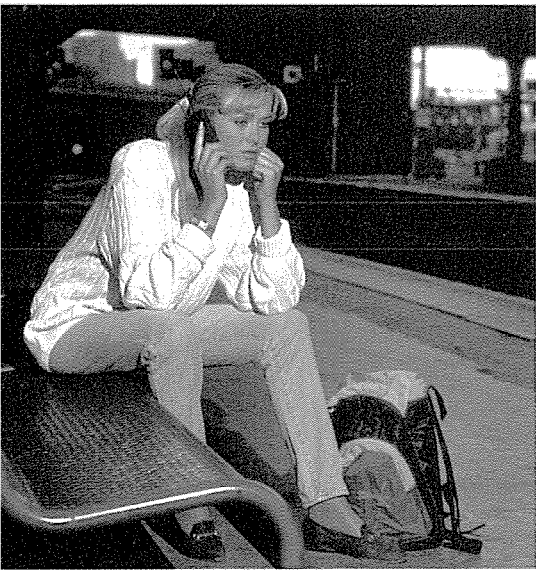
THE MODERN TELEPHONE means that people can be in instant voice contact with one another wherever they happen to be on Earth. But carrying speech is only one task of the global telecommunications network of today. Huge quantities of computer data, fax messages and other types of electronic information are routinely sent down the phone lines as well.

Many phone links still rely on coaxial, or 'coax', cable. Each cable consists of a central copper wire surrounded by a copper sleeve. The sleeve protects the electrical signals travelling along the wire from outside interference. About 20 individual coax cables are bundled together, inside a metal sheath and a layer of insulating plastic to make a long-distance cable. This is then laid under the ground or on the seabed.

Among the problems with coax is that it is heavy, bulky, and can handle only a limited amount of information at once. Fortunately, scientists have found an ideal replacement for it -

Peter Poulides/Tony Stone Photo Library, London





Cordless phones are now extremely common and can be used over a wide area. Phone account and credit card calls have heralded a communications revolution.

cables can handle far more telecommunications calls than a copper coax ten times as thick. But new developments promise even better performance in the future. In theory, a vast amount of information can be sent down an optical fibre phone line. This is because, unlike electrical signals which interfere with one another, light signals can overlap without getting mixed up.

Regenerators

The problem is that the light signals weaken as they travel along. As a result, they must be amplified by devices known as repeaters - or regenerators - that are set up along the optical fibre every 100 km.

In present systems, the light pulses have to be converted to an electronic form before they can be boosted. The

The new generation of phones means that calls can now be made to anywhere in the world from locations where it is not practical to run telephone wires.

amplified electrical signal is then used to power a small laser connected to the next length of fibre. However, repeaters of this type are costly and tend to break down. Fixing them is expensive, especially if they are under the sea. Because of these factors,

optical fibres. As thin as a human hair, each optical fibre is made using two types of glass, one forming a core, the other a cladding that surrounds it.

Unlike coax, which carries waves of electricity, optical fibre transmits pulses of very pure light produced by a laser. Whenever the laser light tries

to break out of the fibre, it strikes the boundary between the core and cladding and is reflected back inside again. In this way, the light zig-zags its way down the slender glass thread over distances of many kilometres.

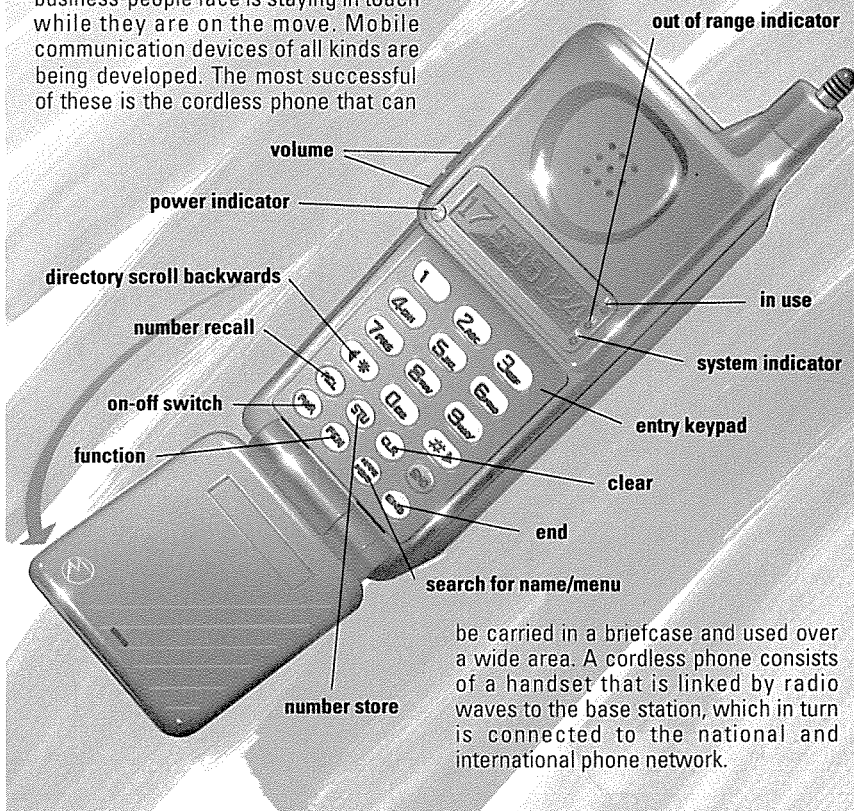
Laser light

Messages to be sent by optical fibre arrive at one end in the form of a varying electrical signal. This signal causes a laser to switch on and off very rapidly. The resulting pulses and no-pulses of light from the laser are then used to carry information in a similar way to the dots and dashes of Morse Code.

Optical fibres are bundled together to make a flexible cable about as thick as an index finger. Already, such

CORDLESS PHONES

In the fast-moving information age of the 1990s, one of the biggest problems business-people face is staying in touch while they are on the move. Mobile communication devices of all kinds are being developed. The most successful of these is the cordless phone that can



be carried in a briefcase and used over a wide area. A cordless phone consists of a handset that is linked by radio waves to the base station, which in turn is connected to the national and international phone network.

Time used to be wasted travelling from place to place. But these days it is possible to make telephone calls from trains and cars and planes.



researchers are trying to develop new ways of amplifying light signals that do not depend on first converting them to electrical form.

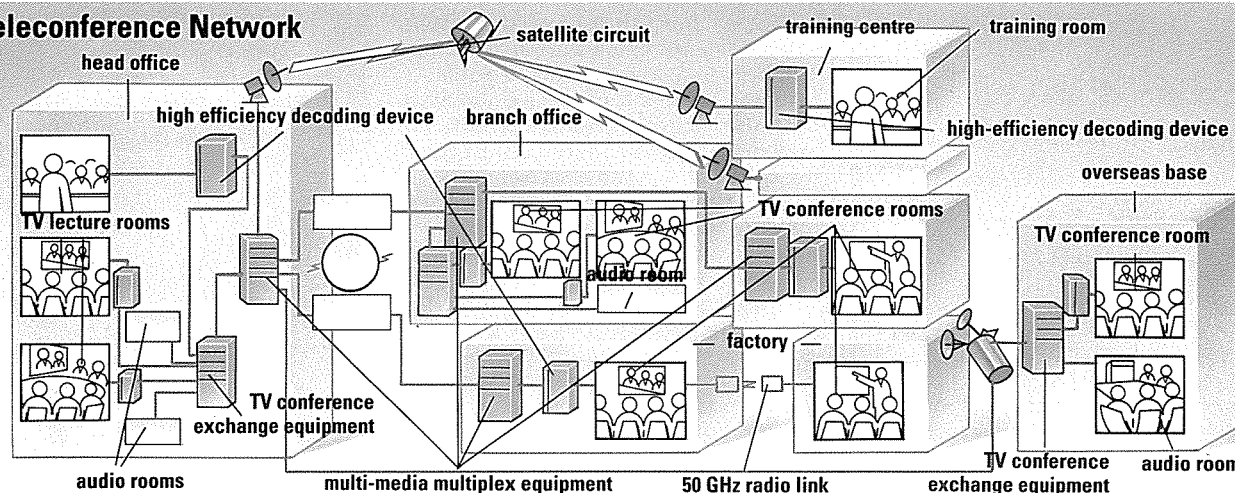
'Doped' cables

One of the most exciting breakthroughs came from the Japanese communications firm Nippon Telegraph and Telephone (NTT). Scientists at NTT made repeaters using lengths of optical fibres that had been carefully blended, or 'doped', with atoms of the rare element erbium. The erbium atoms are energized by light of a very specific wavelength. They then re-emit this



Teleconferencing makes travelling almost irrelevant. Business meetings can be held face to face on the phone. Diagrams and computer data can be exchanged between the participants at the same time.

Teleconference Network



Joe Lawrence

light so that the strengthened outgoing waves are exactly in step with the weak incoming waves. They act in the same way as a laser.

Record distance

Using 25 erbium repeaters, each 160-metres long, separated by 80 km of standard optical fibre, the NTT researchers were able to send 2.5 billion bits of data across a record-breaking distance of 2,223 km.

For many years, science fiction

Teleconferencing systems link up specialized conference rooms both within one country and internationally using high-speed digital circuits, satellite communications, in-house, optical fibres and radio links.

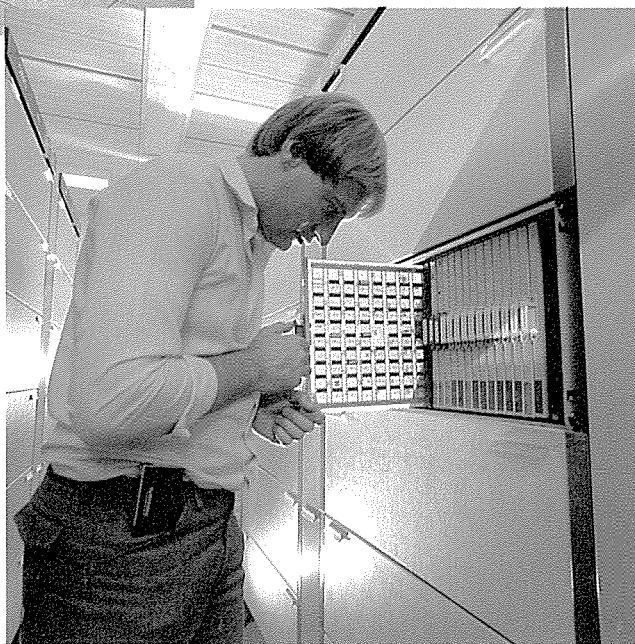
writers have heralded the video phone. The idea is that this would allow callers to see each other on a small television screen while they were carrying on a conversation.

But there is one big problem with such a device. While ordinary speech requires a data communication rate – or bandwidth – of only about 250 bits a second, to transmit a standard television picture takes about 80 million bits per second! Special equipment can be used to compress the video information since many parts of the image do not change from one frame to the next. Even so, if every conventional telephone in use today were suddenly replaced with a video phone, the global telecommunications network would be jammed within moments.

Video conferencing

Rapid progress is being made, however. For the past several years, large companies have made use of a facility called video conferencing. This connects people at distant sites with sound and video pictures transmitted along special phone lines. In 1986, video conferences cost over £500 an

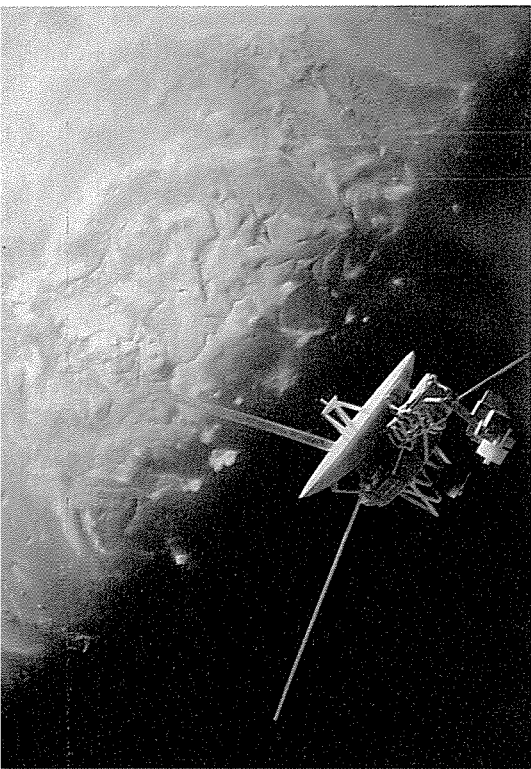
British Telecom's System X brings digital processing and the latest microchip technology to the telephone exchange. Banks of microprocessors in huge units (above) make diagnosing problems and curing faults easier.



E Pritchard/Tony Stone Photo Library, London

Telefocus





The world's longest distance communications are literally out of this world. Radio signals broadcast by the Space probe Voyager 2 as it flew past Neptune in 1989 took more than 5 hours to reach the Earth. Such long delays make it impossible for controllers to issue commands to a spacecraft during critical parts of the mission. Instead, a carefully planned sequence of manoeuvres and experiments has to be stored in the probe's onboard computer well ahead of time so that they can be carried out automatically.

Optical fibres will reduce the cost still further, enabling people to install videophones in their own homes. At present, optical fibres are only used for linking central switching offices and long-distance connections under the ocean. But in the next decade, this technology will extend into the home, making the videophone into a reality.



Facsimiles

Another device that plugs into the phone network is already proving enormously popular and useful. This is the fax – or facsimile – machine. Any document – a printed page, a handwritten note or a picture – can be fed into the fax machine. The light and dark areas of the paper are scanned.

A photosensitive cell responds to the variations in light intensity as a fluorescent lamp shines on to the paper. Electrical pulses are produced by the cell that correspond exactly to the regions of varying brightness on the

Running telephone systems still requires manpower. Part of the engineer's job is to climb poles in country areas and repair or replace broken lines.

Just amazing!

WRONG NUMBER

THERE ARE NOW MORE THAN 600 MILLION PHONES IN THE WORLD – TWO FIFTHS OF THEM IN THE UNITED STATES.

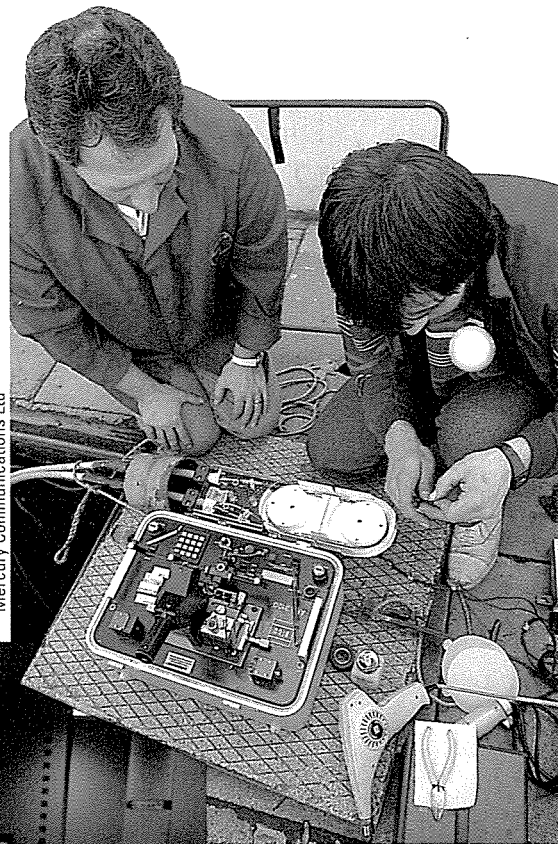


Paul Raymond

Julian Baum/Science Photo Library

hour on dedicated phone lines that had to be reserved days in advance, and required up to £250,000 of electronics on each end. By 1990, higher speed, coax lines had dropped the cost to just £15 per hour and a need for only £60,000 worth of data handling equipment at each end.

G Finlayson/Tony Stone



Mercury Communications Ltd

Modern telephone systems are controlled by computer, which can instantly diagnose faults. Fibreoptic cables (above) will improve capacity, but joining them is a complicated business.

Peter Ryan/Science Photo Library

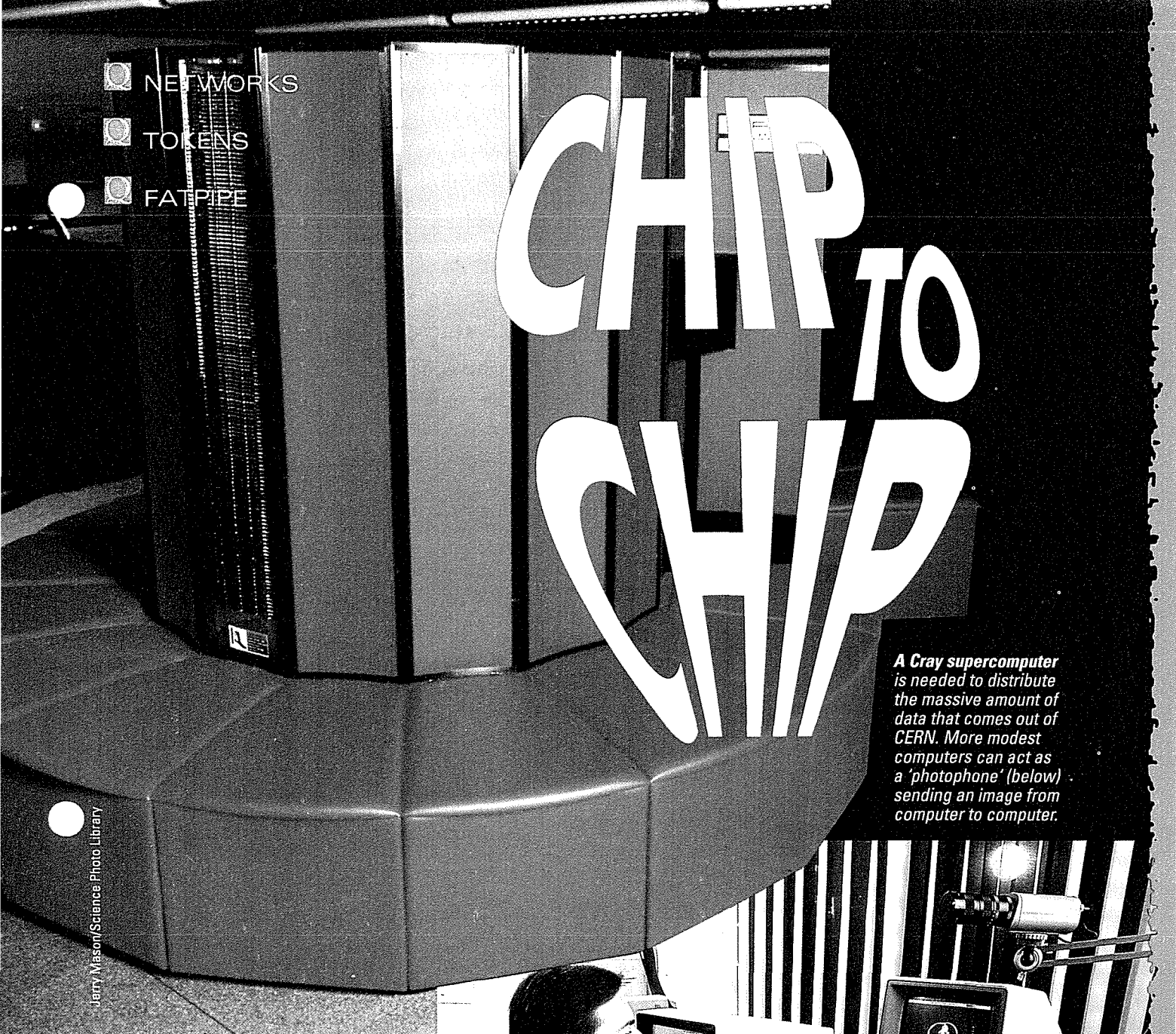


page. The fax machine then converts this electrical signal into a 'warbling' collection of high and low tones, which can be transmitted by phone to another fax machine. The receiving fax creates a copy, or fac-

simile, on an electrostatic printer.

Among the latest telecommunications products are special automatic switches that allow people to receive fax messages and ordinary telephone calls on the same home or office line.





■ NETWORKS

■ TOKENS

■ FAT PIPE

CHIP TO CHIP

A Cray supercomputer is needed to distribute the massive amount of data that comes out of CERN. More modest computers can act as a 'photophone' (below) sending an image from computer to computer.

Jerry Mason/Science Photo Library

LINKED TOGETHER INTO networks, computers can talk to each other – across a room, throughout a building or even around the world.

The largest computer network in the world is Internet, which was developed in the United States. It now connects more than 30 million users, from multinational companies to individuals.

At the other end of the scale are local-area networks (LANs) that may include only one or two computers and serve a single organization. These local-area networks have become extremely popular in medium-to-large companies, research laboratories and universities.

Local area networks allow all the resources of the network to be tapped from any workstation or terminal. Printers, magnetic storage devices and other valuable equipment as well as the power of the computers themselves can be shared

by all users. All they need is a terminal – that is, a keyboard plus a monitor – which is plugged into the network.

Security

Using a LAN, a person at one terminal can send messages, known as electronic mail, to other people in the same network. These messages are flashed up immediately or when the person they are intended for switches on their monitor. In the same way, employees can work collectively on designs for new products, share com-

mon databases or solve a problem by exchanging data through the network. It is possible, of course, to secure sensitive or confidential files on a terminal, allowing the network access only to 'published' files.

LANs are built around a single coaxial cable or a pair of wires. The particular way a network is arranged and equipment connected to it is called the network topology. A common arrangement with LANs, for instance, is the token-ring network. This involves a token, or fixed string of



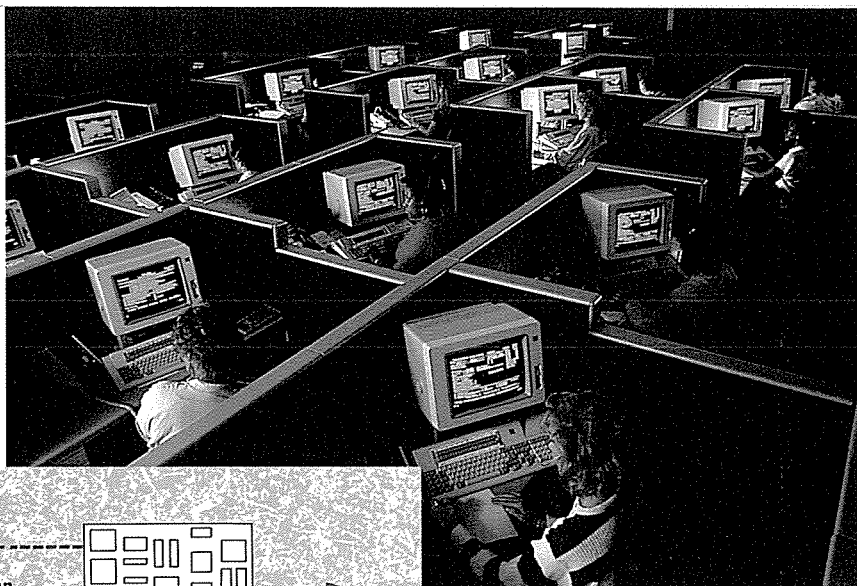
Simon Fraser/Science Photo Library



data, travelling around a closed loop to which the various pieces of computer equipment are linked.

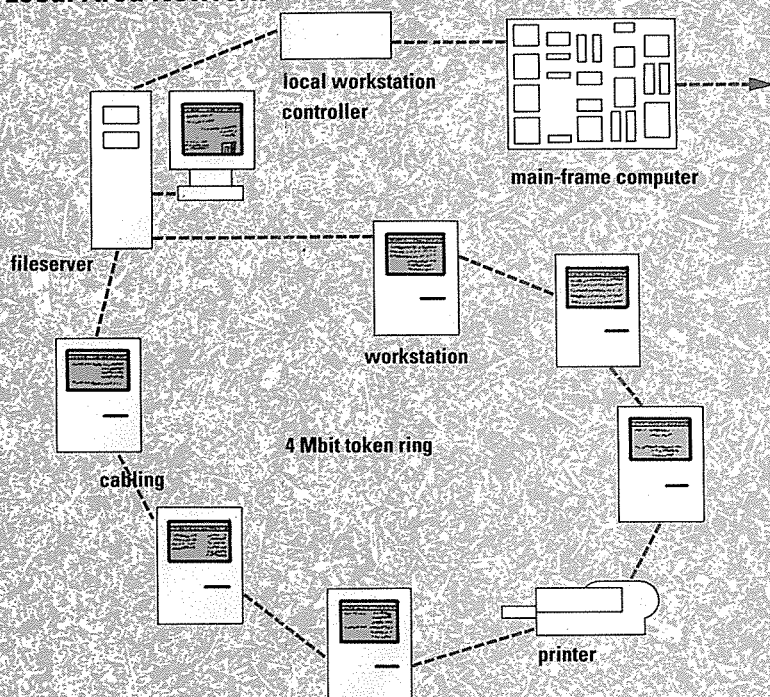
In order to send information to another part of the LAN, a machine must first intercept the token as it goes past. It then removes the token temporarily.

In modern offices, computers are tied together in local-area networks (below). Information can be passed between them and data can be shared.



T Tracy/ZIFA

Local Area Network



Mark Franklin

porarily and inserts a 'packet' of data into the network ring followed by the token. This packet carries an address, which is the identifying code of the machine to which it is being sent. The receiving machine recognizes its own identifier and removes the packet before the token has a chance to make a

full circle. In a sense, the token is like a shunting engine that pushes data from one part of the network to another while making sure that no collisions occur on the ring.

Today's token ring LANs can transmit data at a rate of 10 megabits (10 million binary digits) a second. Experimental rings built of optical fibres, instead of wires, have achieved rates of more than 100 megabits a second.

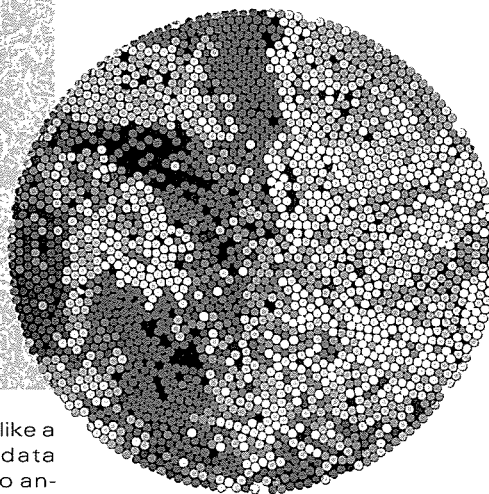
Larger networks that link big companies across hundreds or thousands of kilometres make use of phone lines for sending information. These tend to be much slower. But recently, a new high-speed data link was opened between the US and Europe that will revolutionize computer collaboration between these two continents.

Optical fibres

The new link, called fatpipe, has a capacity of 1.5 megabits a second, or the equivalent of 200,000 characters – approximately the number of letters in four issues of *Quest* – a second. To begin with, fatpipe will improve data links between American scientists and researchers at CERN, the European centre for high-energy physics in Geneva. Eventually, CERN will receive data from fatpipe and distribute

it around a network called the European Supercomputer Network.

Optical fibres will bring about the next major breakthrough in networking. Nations across Europe, North America and the Far East are already replacing large sections of their phone lines with optical cables.



Fibreoptic cables will carry the data streams of the future. Viewed end on, all you see is a pattern of brilliant light.

Martin Dohrn/Science Photo Library

NEURAL NETS

Networks can connect different computers together, or they can connect different parts within the same computer. A new type of computer is currently being developed, known as a neural network. This works in a similar way to the human brain. Inside it, several hundred or thousand small processors are connected together. Each processor can exchange signals with a number of other processors nearby. The arrangement of connections inside a neural net mimics the way that brain cells are joined together. Just as in the brain, the output from any processor depends on the combined strength of the signals it receives from its neighbours. This may allow a neural network to learn from its mistakes and so solve complex problems 'intelligently'.

Just amazing!

WORM'S EYE VIEW

WHEN IN NOVEMBER 1988 A 'WORM' – A PROGRAM WHICH DESTROYS DATA – WAS SET LOOSE IN AMERICA'S LARGEST COMPUTER NETWORK, IT TOOK 50,000 MAN HOURS TO ERADICATE IT.



Paul Raymond



HOT OFF THE PRESS

GONE ARE THE DAYS WHEN reporters sweated over ancient typewriters to hammer out the latest story. Fast disappearing, too, is the method of laying out pages for a new book or magazine by the method of 'cut and paste'. In the past few years the world of publishing has been transformed by the arrival of computers and various other pieces of hi-tech equipment.

The production of newspapers, for instance, has been completely revolutionized. Until recently, a reporter covering a story in the field would produce a rough draft of an article using a typewriter. Then this would be relayed to the central newspaper office by telegraph or by reading it aloud over the phone to a 'copytaker', who would type it as it was being read. Then it would be passed on to a sub-editor for any changes of style or length to be marked in by hand.

Tony Whitehead/Reuters Photo Library



Many newspaper and magazine journalists now write and edit articles on WIDIU (visual display unit) screens.

Paper passes through web-offline printing presses, used in newspaper production, at speeds of 450 metres per minute.

Dick Luria/Science Photo Library



Today, that same reporter can simply tap out the story on the keyboard of a 'lap-top' computer. Battery-operated, this is no bigger than a large book, but has all of the properties of a fully fledged word processor. It is an easy matter to alter text, change the

A typesetting machine sets type photographically and stores it on a computer disk - a system called photocomposition.



Eric Brissaud/Gamma/Frank Spooner Pictures

Electronic scanners have filters that break down colour pages into primary colours, which appear as a dot pattern. The scanner calculates how many dots are needed to reproduce each of the colours in the original. Four sheets of film are used to make printing plates.

et. But the reporters who travel from country to country may not have the appropriate plugs, or there may only be a call phone box. On these occasions the reporter will use an acoustic coupler. This converts the electronic pulses representing the text into a series of audible beeps that travel down the phone line to a modem and computer at the newspaper office. Once received, there is no need for retyping, and the story can be routed directly through to the newsroom. It need never be printed out until the newspaper itself is printed.

In a newspaper office, the incoming story is read on screen by a news

order of sentences or search an entire article for a particular group of words or letters and if desired change them. The lap-top computer has a liquid crystal display that can show a full screen of 30 lines or so of text. The machine may have up to 500 megabytes of hard disk storage or a standard 3.5 inch floppy disk drive for storing large amounts of text.

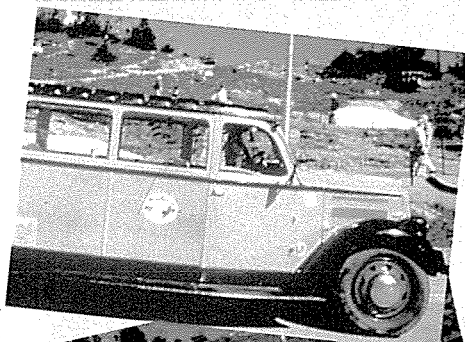
Crosfield Electronics Ltd



Electronic mailbox

Once the story is written, the reporter will phone the newspaper's electronic mailbox and send the story over the phone lines, using the lap-top's internal modem. The connection to the phone system may be a cable plugged into a standard phone sock-

COLOUR RETOUCHING BY COMPUTER



Advances in print technology have made it possible to change and improve colour pages before printing. Retouching (once done by hand) is now carried out on a computer screen.

At the push of a button, the operator can enhance the whites of a fashion model's eyes, brighten a dark sky or turn a red car into a yellow car (see pictures, left). This is done by changing the proportions of the coloured dots, called 'pixels', that make up the photograph. The technician outlines the part of the picture to be changed and alters the percentage of pixels until the right tone or shade is reached.

If the image needs to be brighter or whiter he or she simply reduces the amount of black pixels in the right area.

Crosfield Electronics Ltd



3M United Kingdom plc

Just amazing!

MICRO-PAEDIA

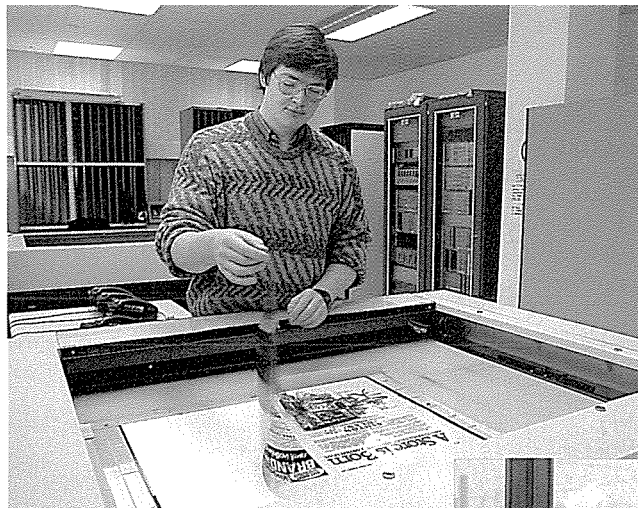
USING AN ELECTRON BEAM LESS THAN TWO ATOMS WIDE, SCIENTISTS HAVE SHOWN THAT IT IS POSSIBLE TO WRITE THE WHOLE OF THE ENCYCLOPAEDIA BRITANNICA ON A PIN-HEAD!



Paul Raymonde



Plate-making is an important part of the printing process. The final pages, containing words and pictures, are printed on to light sensitive film which is then converted into 'plates'. These are image carriers that are attached to the revolving cylinders of the the printing press.



right picture to go with a story, instead of having to wait while a pile of prints are made in a laboratory.

Then, possibly within minutes of the story being written in a distant besieged city, the completed page can be printed out, complete with photographs and illustrations, on a typesetting machine. This may be the first time that the story has been printed on paper – up to now the words have been in electronic form only.

Mike Abrahams/Tony Stone

editor who decides how important it is compared with the other stories of the day, on what page it should be used and how much space should be given to it. The page is designed with this in mind and the story is then sent on electronically to a sub-editor whose job is to make whatever changes are needed to the story so that it fits exactly the space allocated to it.

Typesetters

A newspaper item may have several typesets or type sizes, plus short paragraph headings or 'cross heads' which are put in to break up the appearance of the page and make it look more interesting. To make these appear in the printed form, the sub-editor inserts the appropriate typesetting commands into the story. He or she then writes a headline and sends it back to the

The colour photographs and artwork in most books and magazines (such as this one) first go through a process called colour separation. Every colour page is made of four sheets of film – yellow, red, blue and black. Combining these produces every other possible colour.



Tony Stone Photo Library, London

Today, the major news agencies supply photographs ready-scanned in electronic form to the big newspapers. The paper's picture editor can see all the pictures available on screen and can choose exactly the

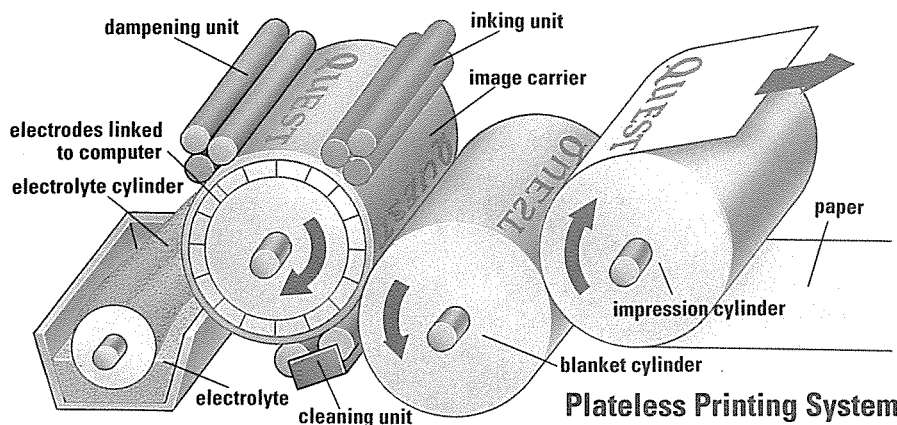
From this page, a printing plate is made so that the newspaper can 'go to press'. Newspapers are usually printed on web-offset rotary presses. In these the paper is supplied on a long roll so that it runs through the press continuously. The plate is fixed round a cylinder, as is the inking transfer blanket, so the pages are printed top to bottom on the roll.

Power press

At one of the world's most up-to-date presses, the British *Daily Mirror* is printed at a rate of 70,000 an hour for a 48-page issue, with up to 16 pages in full colour. A total of 21 presses, in three different locations, can produce some seven million copies of three separate newspapers in one night.

But new technology has stepped in here, as well. At one time, the paper would have been printed in one

Paul Shambroom/Science Photo Library



Mark Franklin

chief sub-editor who looks at the overall page and can make any last-minute changes to the layout.

A photograph or piece of artwork can be added to the page, by inserting the illustration into a device called a scanner, which rapidly measures the brightness level at each of hundreds of thousands of points across the picture. These brightness levels are then digitized and stored as numbers within the computer. The picture can then be recalled on to a screen and its position and size altered to fit in with the rest of the page layout. The picture can even be retouched electronically, by changing chosen picture elements for others with a different brightness.

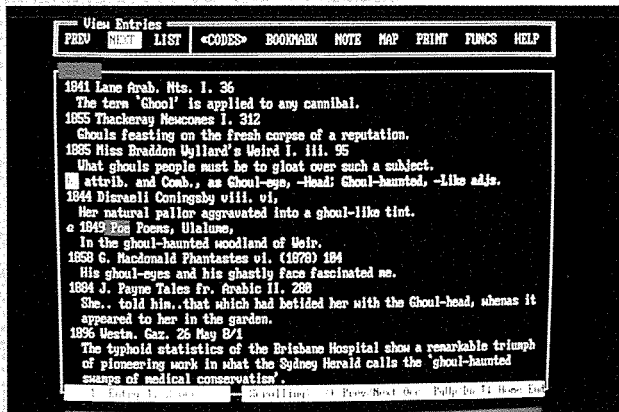
A revolutionary printing system cuts out the need for plate changes. Instead, the image can be changed electronically while the press is still operating.

A computerized fountain control panel on a printing press is used to control the density of the ink and the water balance during the print-run.



place and distributed by train or plane. People in remote areas would receive their news much later than those near the distribution centre. But now the pages can be scanned and sent to other printing plants over data links.

ON-SCREEN OED



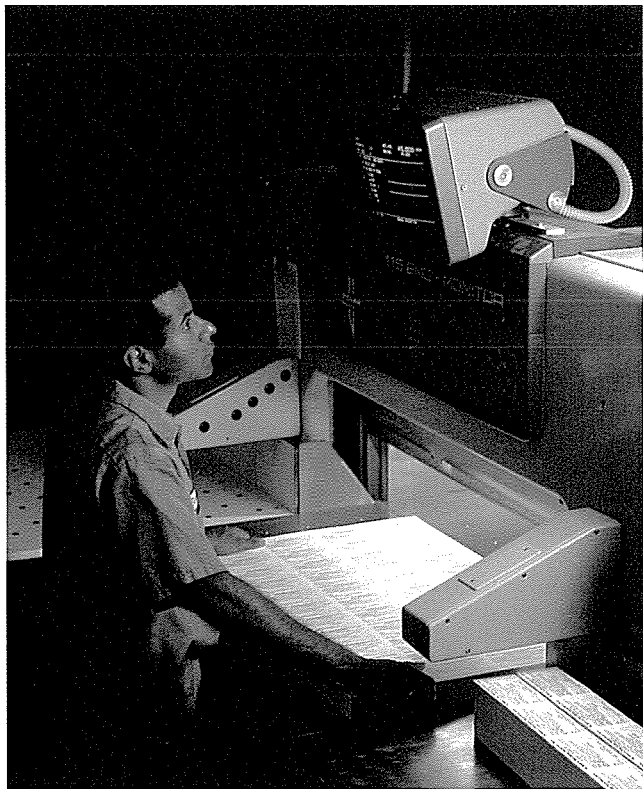
Oxford University Press

One of the most ambitious publishing projects tackled recently with the help of computers is the new edition of the Oxford English Dictionary, OED2. The first edition, covering 400,000 words and phrases, appeared in 20 volumes between 1884 and 1928.

Using IBM workstations and special artificial intelligence software, the OED researchers entered all of the material from the older work and added thousands of new scientific and technical words that have come into common use since the first edition.

Now, with the dictionary fully computerized, it will be easier to update in future and to supply it in new forms such as CD-ROM.

Computerized trimming machines (guillotines) cut the printed material into the required shape and size at the end of each print-run.



Tony Stone Photo Library, London

The newspaper can then be printed in several places at the same time.

The British weekly newspaper, *The Economist*, is produced in four locations around the world as well as in London. In order to send the streams of data that represent the pages to the other locations, the magazine maintains permanent 'dedicated' fibre optic cables. Each page takes five minutes or so to scan, including black-and-white illustrations, diagrams and cartoons. The data is sent in compressed form, so that time is not wasted in transmitting white space. Even the cover, with its full-colour picture, can be scanned, though this takes about ten times longer.

The outlying locations print the magazine from the pages that emerge from their machines. They can distribute the magazine on the same day that it appears in the original location.

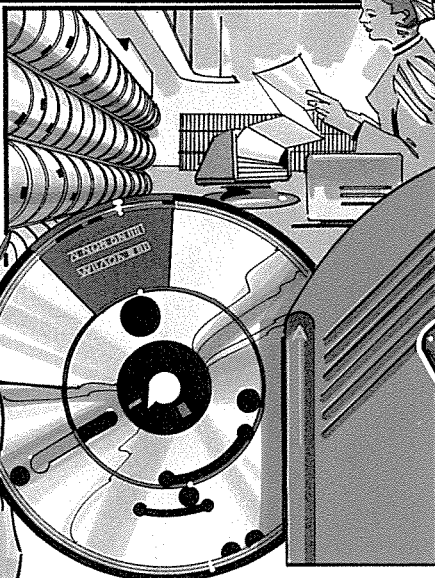
Databases

But even as the paper or magazine goes to press, new technology is still at work. All the text that has been stored on computer for the various pages is stripped of the commands that control the typefaces, so that only the words are left. The whole issue can then be made available as a database so that it is a simple matter to find a particular item.

INTO THE FUTURE

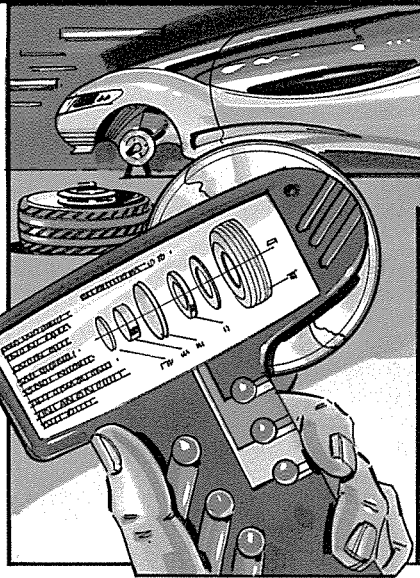


▲ All stages of publishing will become part of a single computerized system – copy will be fed in at one end and the finished product will emerge at the other.



▲ Books and magazines will be paperless and contained on CD-ROM. These will be accessed at libraries and printed out on request.

PAPERLESS PUBLISHING



▲ Hand-held devices, similar to today's portable compact disc players, will display the entire contents of any book, page by electronic page.

Joe Lawrence



HEARING AIDS ARE NO USE TO totally deaf people. They simply amplify sound so that someone who has some residual hearing can hear a little. But totally deaf people can now hear again with a device planted within the ear.

A cochlear implant replaces the functions of the outer and middle ear with electronics. Normally, sound passes down the channel of the outer ear to the eardrum. The eardrum vibrates and the sound vibration is transmitted through three tiny bones to the cochlea. This is filled with the perilymph fluid whose movement is detected by tiny hairs. The hairs sort out the sound frequencies and turn them into nerve impulses, which are sent to the brain.

Auditory nerve

Even in the totally deaf, some of these nerve fibres remain. If they are stimulated directly, they will still convey messages down the auditory nerve to the brain, so that some form of hearing can be restored.

To do this, the cochlear implant is placed inside the inner ear. It consists of a tiny, plate-like, radio receiver with a long tail. The device is implanted inside the ear by a surgeon. The receiver lies beneath the skin, just behind the ear and the electronic tail is pushed inside the curl of the snail-shaped cochlea.

Electrical impulse

Outside the ear is a microphone that picks up sound. The signal is passed to a small computer - a sound processor - which converts the sound into electrical impulses. These impulses are then sent back up to a tiny transmitter that sits behind the ear directly over the receiver. When the receiver picks up the processed sound signals, it passes them down to the electrodes inside the cochlea.

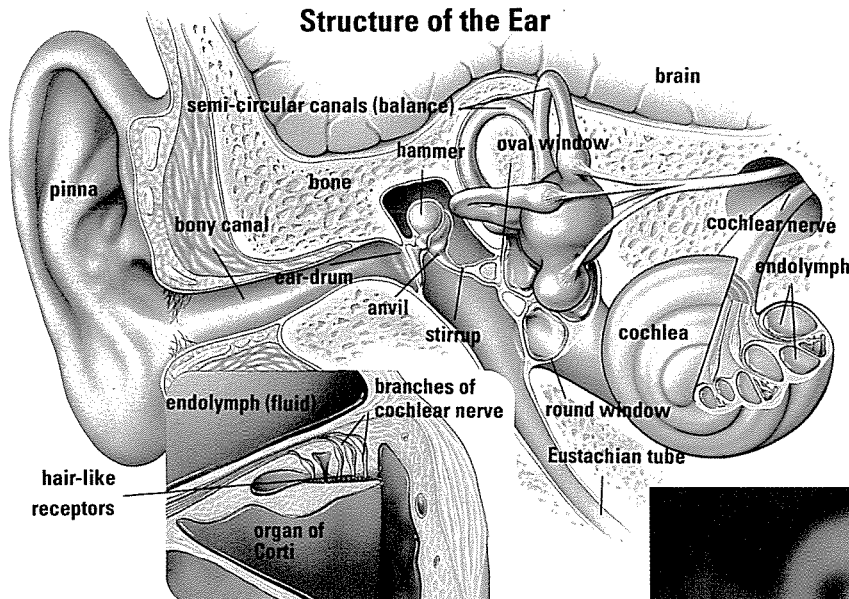
Exposure to loud noise can damage the tiny hair cells in the cochlea and result in deafness. If your ears 'sing' afterwards you are probably doing damage to your hearing.

HAIR CELLS
SOUND PROCESSOR
SURGICAL IMPLANT

HEARING



Structure of the Ear



Frank Kennard

The simplest type of cochlear implant has just one electrode on this tail and is called a single channel implant. It stimulates the nerve fibres and sends just one electrical signal to the brain. The signal matches the sound waves picked up by the microphone, but it is left to the brain to try to sort out the frequency patterns, a job normally done by the cochlea.

A cochlear implant bypasses the damaged parts of the outer and middle ear and stimulates the nerve receptors in the cochlea's organ of Corti directly.



James Stevenson/SPL

The cross-section of an ear that shows the cochlear implant in place. Each tiny metal band is an electrode.

multichannel implant it is not certain that someone will hear clearly enough to be able to have a telephone conversation. But they will, with practice, recognize the different sounds around them and will usually be able to lip-read more easily. This makes a big difference to everyday life and to personal confidence.

This X-ray shows the tail of the cochlear implant and its electrodes curled up in the snail-shaped channels of the cochlea. To the left is the receiving unit that decodes the signal from the sound processor and sends it to the appropriate electrode.



Other implants are more complex and have a string of electrodes along the tail – as many as 22 – situated at different places in the cochlea.

In multichannel implants, signals are sent to different parts of the cochlea depending on the frequency pattern of the sound picked up by the

microphone. The multichannel sound processor also has to be more complex and works more in the way the ear normally works than a single channel implant. It is still, however, extremely crude compared with the finely detailed sound analysis made by the healthy human cochlea.

Once the surgical implant has been made, an audiologist programs the sound processor so that the maximum stimulation of the cochlea occurs. This electrical stimulation is then reinterpreted by the brain and heard as sound. In this way the deaf can hear again.

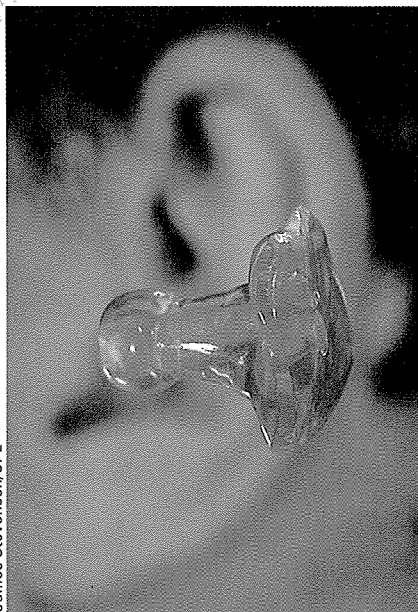


In touch again

For people who have lost their hearing completely, an implant can put them in touch with sound again, provided that their auditory nerve is still working. But having a cochlear implant is not like getting back perfect hearing. The sound is often very strange and takes a lot of getting used to.

Implants are not suitable for people born profoundly deaf. People with no experience of sound cannot make sense of what they hear.

Even with a



An ear dilator is implanted to improve the size of the external auditory meatus – the passage that leads from the outer ear to the ear drum. This simple device can make all the difference to someone who is going deaf.

Just amazing!

AN EAR FOR MUSIC

BEETHOVEN WAS TOTALLY DEAF WHEN HE WROTE HIS NINTH SYMPHONY. AT THE PREMIERE HE WAS STILL CONDUCTING AFTER THE ORCHESTRA HAD FINISHED.



Cochlear AG

Paul Raymonde



● TOUCH SENSORS

● LEARNING

● MOBILE ROBOTS

HELPING HANDS

MOST OF TODAY'S ROBOTS are industrial machines, programmed by computer to carry out specific tasks in a factory. But when it comes to robots that can make some kind of sense of the world around them by 'seeing', 'hearing', 'feeling', 'smelling' or even 'tasting', the technology involved becomes far more complex.

When people do everyday things such as read a letter or listen to the radio, they are using a complex physiological and psychological system, part of which involves their senses. Without this system, is it really possible for a man-made robot to perceive the world around it?

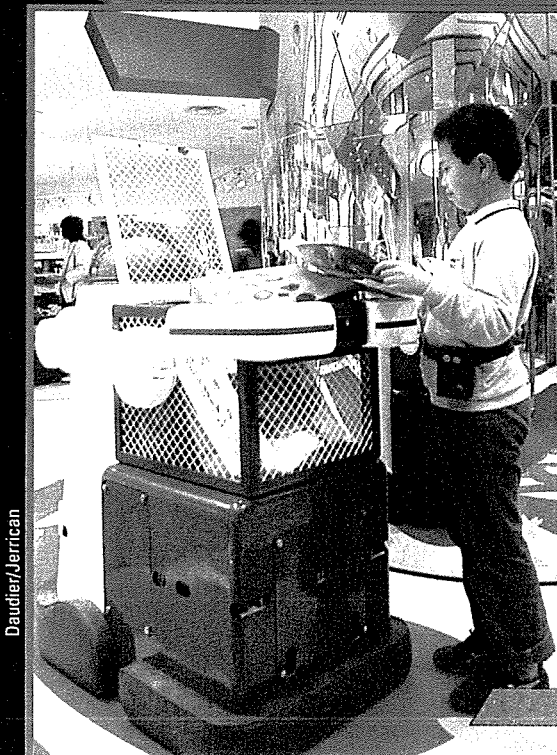
In many cases, a robot is a mechanical arm that is controlled by a computer. In fact, all the recent advances in robotics are a direct result of the advances in general computing. When we talk about a robot's ability to 'see' or 'hear', we are in fact talking about the computer's abilities.

Computers are merely able to manipulate information that is in the form of numbers. This means that any information, even if it describes colours or patterns, has to be represented in numerical, digitized form so that the computer can understand it.

● Learning processes

Even the most advanced robots today can do little more than walk around a room without actually bumping into anything, let alone realize that a phone is ringing or let the cat out. Such tasks involve not only enormous computing power in order to distinguish a telephone from, say, a cat but also a massive amount of learning. There is more to this than showing a picture of a telephone and a cat to the robot. It may come across them from all sorts of angles and in many different situations. It needs to know how each must be treated - it must not pick up the cat like a telephone.

Humans discover this while they are very young - their parents show them the right way to do things. So before scientists can train robots, they need to find out how children learn about the world around them. This

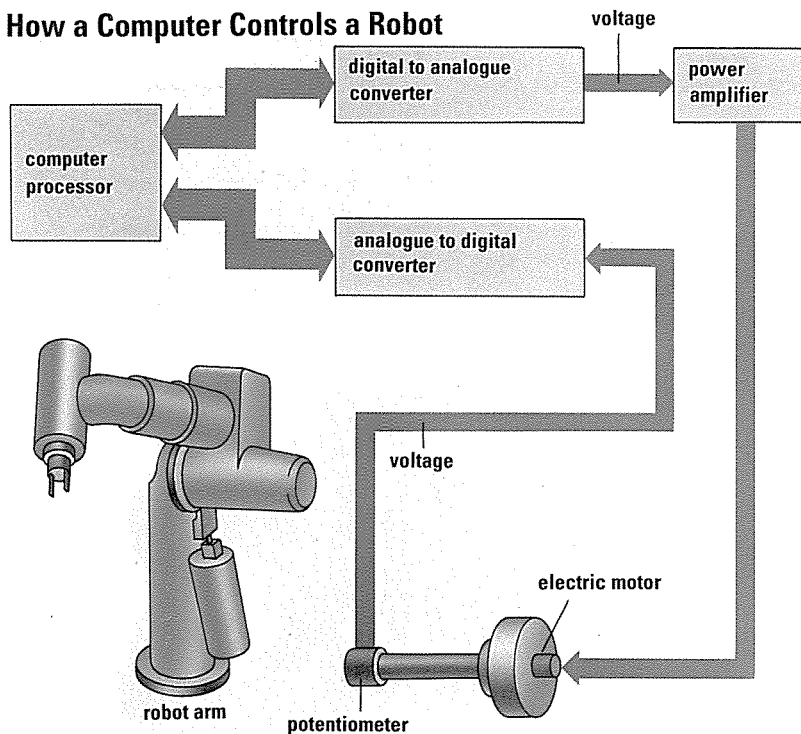


Two diverse uses for modern robots - printing circuit boards in the electronics industry and entertaining shoppers in a Japanese shopping centre.

Tony Stone Photo Library, London



How a Computer Controls a Robot

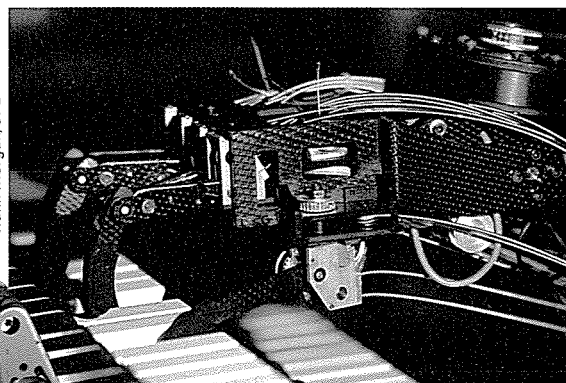


Mark Franklin

means learning masses of apparently trivial and disconnected information about the way things feel and move, fall if knocked over and so on. In the case of the human, this has to be learned by trial and error. With robots it may be possible to teach one laboriously just as if it were a child, then copy its circuits so that all its fellows will know how to behave. But computing power may be the main limitation – the human brain has a huge storage capacity and it is designed for living in the world. A robot,

The computer calculates the voltage required to move the robot's arm to each new position. The electrical charge is then amplified to the correct level for driving the motors.

Hank Morgan/SPL

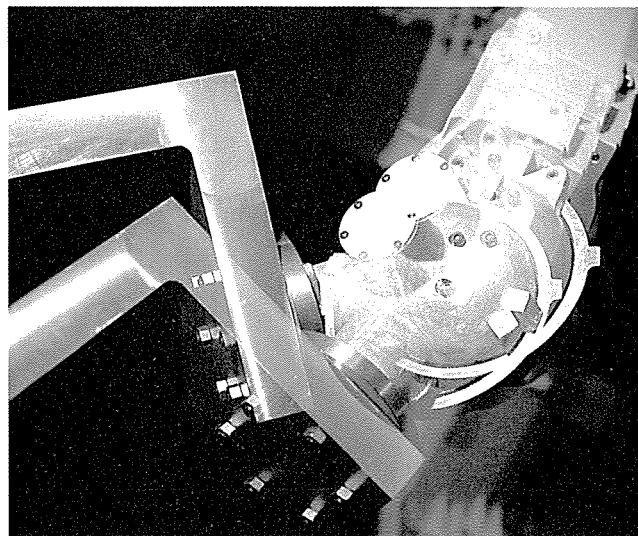


M Bertineti/SPL

computer that an object consisting of four perpendicular lines of equal length is a square. This sort of robot has wide industrial uses – it can be used, for example, to pick out broken biscuits from a factory conveyor belt.

One type of touch sensor consists of two optical fibres inside a cylinder. At one end of the cylinder is a flexible

A robotic, prosthetic hand uses feedback signals from sensors (left) and is controlled by a micro-controller. The 'Salisbury hand' (above) has a 9° freedom of movement. Industrial arms (right) can perform only a few tasks by comparison. Japanese scientists have even developed a robotic hand that can play an organ (above right).



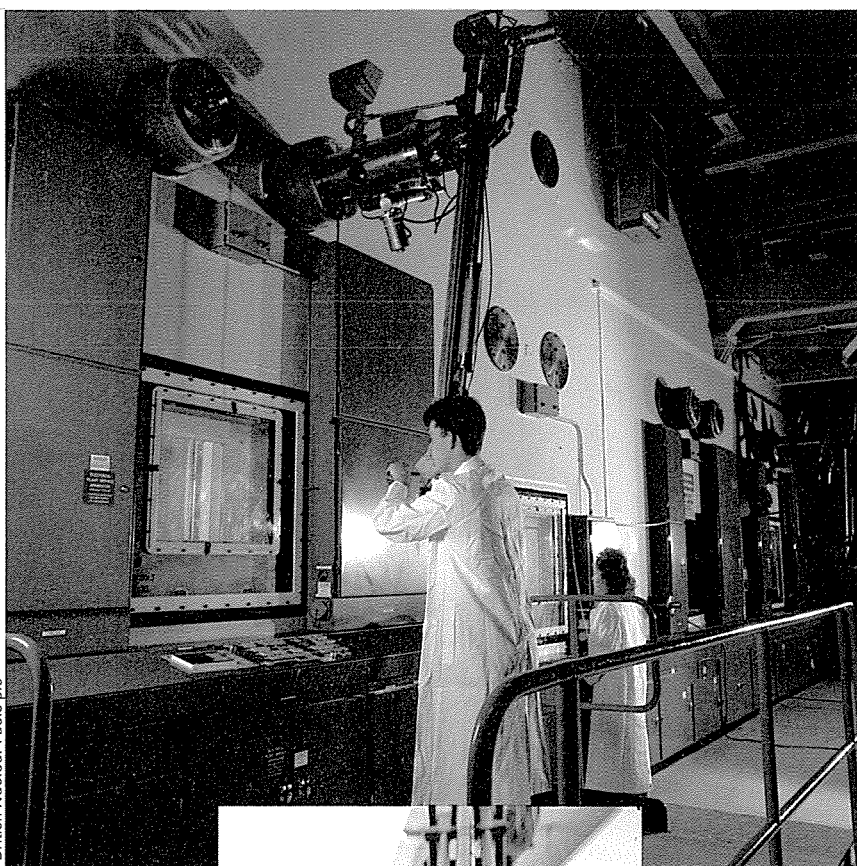
Paul Brierley

on the other hand, may need a separate circuit board for each purpose, rather than being fully capable of every task demanded of it.

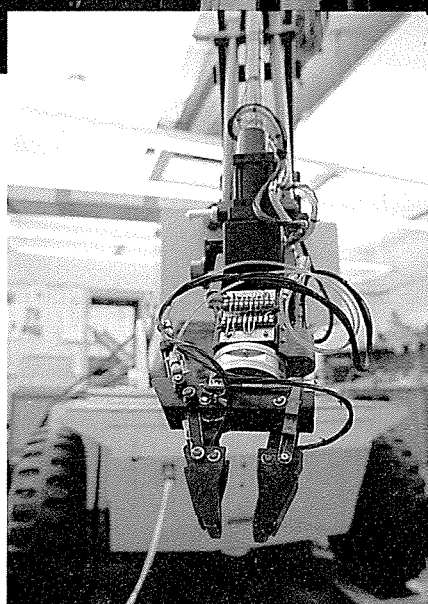
In the human body the eyes, ears and touch sensors produce electrical impulses that are carried via the nerves to the brain. In a similar way, robots are equipped with sensors that provide the computer with information about the world around it.

There are two main types of sensor – those used to 'touch' (called contact sensors) and those used to 'see' or 'hear' (called non-contact sensors). Whatever the type of sen-

British Nuclear Fuels plc



Workers at nuclear power plants use robotic arms and master-slave vehicles (right) to handle radioactive material kept in sealed chambers. Robot arms are also used to check conditions in the most radioactive part of a nuclear plant – the core.



Jerry Mason/Science Photo Library

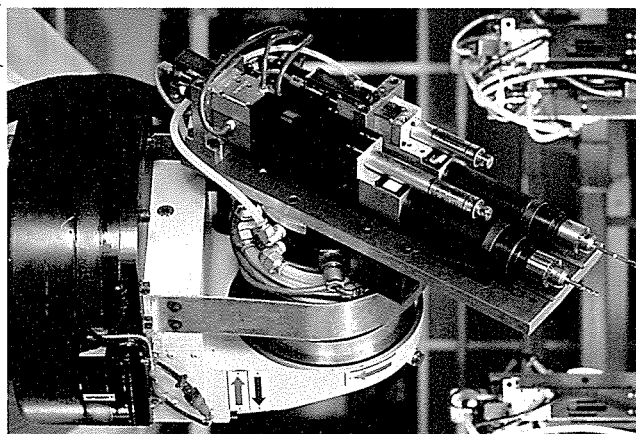
The arm of an industrial robot used to drill and deburr holes. Whereas the human arm has about 43° of freedom, most robot arms have only 5-6° of freedom. This is enough, however, to enable them to carry out a wide variety of repetitive tasks.



Digitized sound

A robot can also be made to 'hear'. This involves connecting the computer to a microphone. The microphone produces a voltage in response to sound. Every sound is represented by a series of numbers and the controlling software program tells the computer what different sounds (and even words) mean.

Computer programs have been de-



Dick Luria/Science Photo Library

Mobile robots are equipped with an in-built computer, or are connected to a computer by cable or a radio link. In factories they can be guided along lines by electromagnetic signals picked up from cables buried beneath the floor.

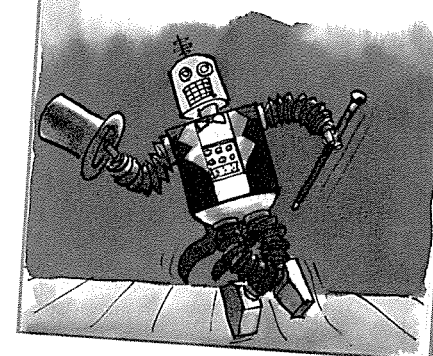
veloped to give robots the ability to recognize spoken commands. A microphone converts the verbal wave patterns into electricity. The waves vary according to the different sounds in each word. These measurements are recorded as a sequence of numbers, and then turned into a digitized code of 'pulse' and 'no pulse' bits. The computer then uses this code as a means of identifying the word.

Computers are capable of measuring voltages very accurately. This is

Just amazing!

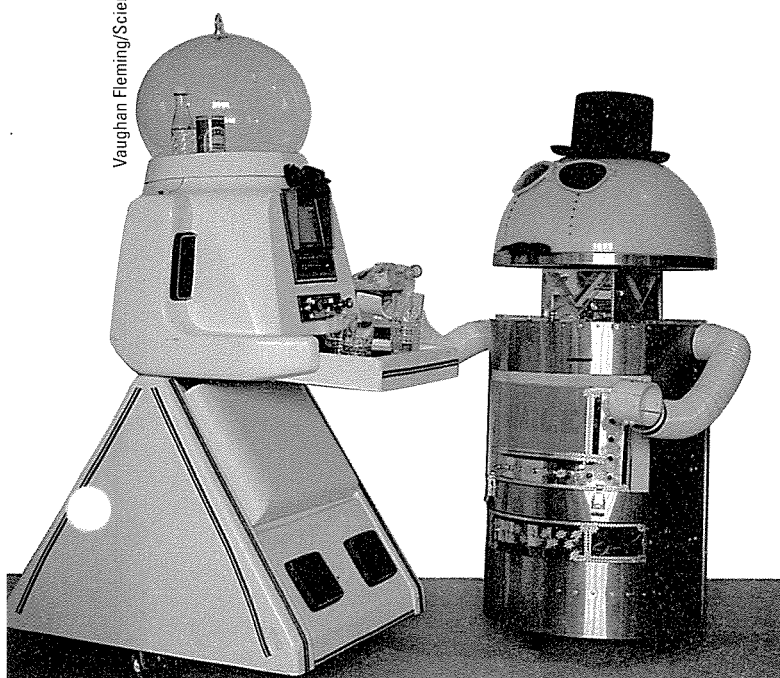
MOBILE DISCO

ONE OF THE ENTRANTS FOR THE 1990 'ROBOT OLYMPICS' WAS A ROBOT NAMED RALPH WHO SANG AND DANCED WITH THE CROWD.



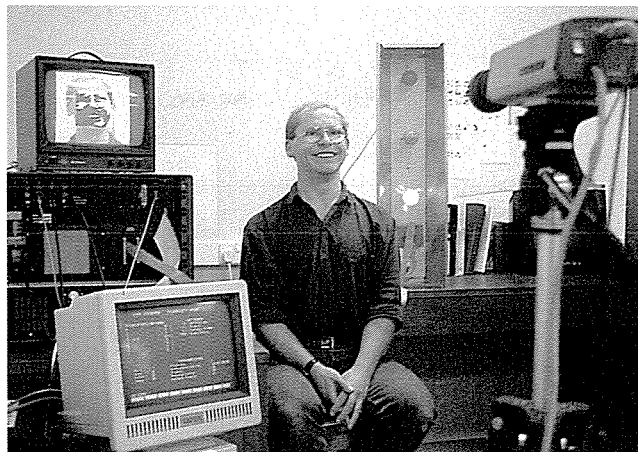
Paul Raymonde

Vaughan Fleming/Science Photo Library





Voice commands can be used by stroke victims and people who suffer from debilitating diseases to operate computers. The system provides access to telephone systems and remote data banks. A robotic arm retrieves hard data from files, loads floppy disks and performs other office and domestic tasks.



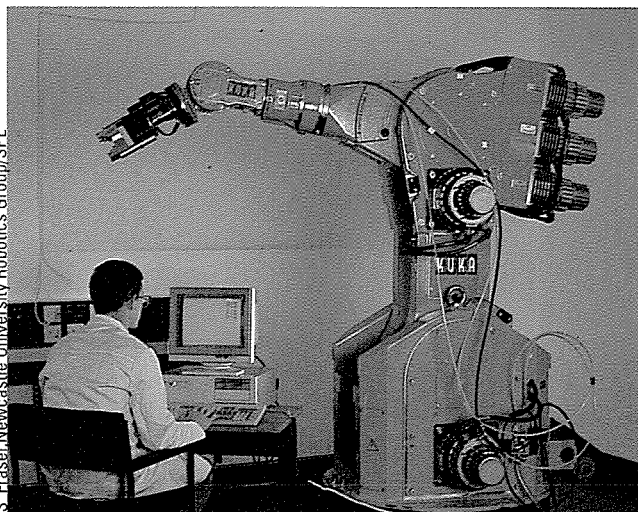
Neville Miles

done by a chip called an analogue to digital converter (ADC), which is connected to the equipment outside the computer. The converter continuously feeds the computer with numbers that are a measure of the voltage.

Movement control

Computers control a robot's movements as well as its senses. They do this by means of a potentiometer, a device rather like a dimmer switch or a hi-fi volume control – the further it is turned the bigger the voltage it produces. A potentiometer fitted to each of the robot's joints works identically – by varying the amount of electricity passing along the wire. The computer converts this voltage into a number and so knows the exact position of the robot.

Information about the angle of a robot's joints is transmitted to a computer via an optical position encoder. This consists of a disc, marked into coded segments, which is attached to



Fraser Newcastle University Robotics Group/SPL

Robots can now be programmed to recognize different faces. The system works by isolating and memorizing groups of pixels (the black and white dots that make up the screen image).

An engineer tests a robot using a computer simulation. The robot's visual and tactile sensors allow it to perform delicate operations.

the moving parts of the robot. A fixed position head, containing a set of small light detectors, 'reads' the marks on the disc and sends a digital message to the computer, which converts it into an angular measurement.

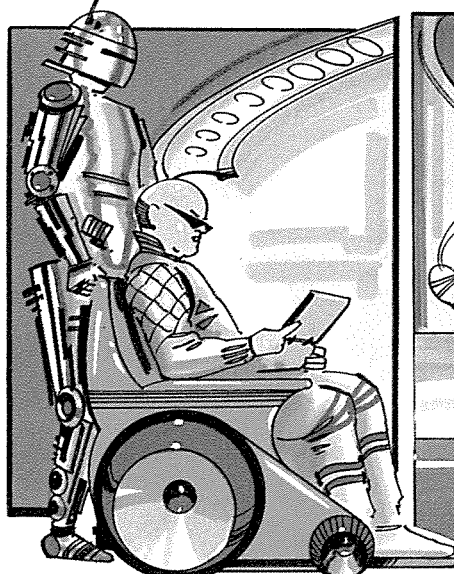
Mobile robots calculate their position by means of ultrasonic sensors that transmit 'bleeps' of sound. A computer then works out the distance from the time it takes the echo to hit an object and come back.

INTO THE FUTURE

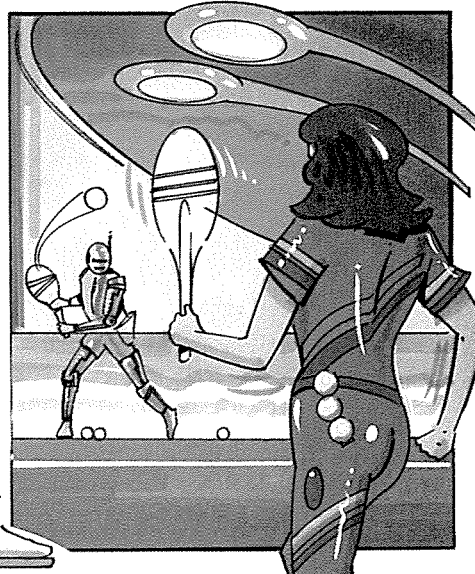
MECHANICAL PLAYMATES



▲ Robots would make the perfect companion for the lonely. Mechanical pets would be affectionate – without needing to be taken for a walk!



▲ Human versions could care for the sick and the elderly and assist the housebound by performing menial, domestic tasks.



▲ Robots will be programmed to take part in a wide variety of leisure activities, providing partners for people wanting to improve their sports skills.

Joe Lawrence

SEA SPEED



The Royal Navy's type 23 'Duke' class frigate is powered by a gas turbine for high speed battle stations. Diesels provide electricity for quiet running.

Royal Navy/TRH

A TITAN OR ARIANE ROCKET, blasting its payload into Space, may develop a million horsepower for a minute or so but a marine engine is designed to produce tens of thousands of horsepower year in, year out, reliably and economically.

There are many types of marine engine. For instance, the diesel of a half-million tonne tanker (or ULCC, Ultra Large Crude Carrier) will need to propel the ship at a steady 16 knots for a month at a time after dropping her pilot off in the Persian Gulf.

Bulk carriers

The engine of a small 25,000-tonne ship burns about 36 tonnes of bunker fuel a day. A 300,000-tonner burns some 132 tonnes. This means that twelve times as much cargo can be shipped for under four times the fuel bill. Even better, the larger tanker is physically only a little more than twice

the size of the smaller, with a crew only half as large again. This is why tankers, bulk carriers and container ships are so large.

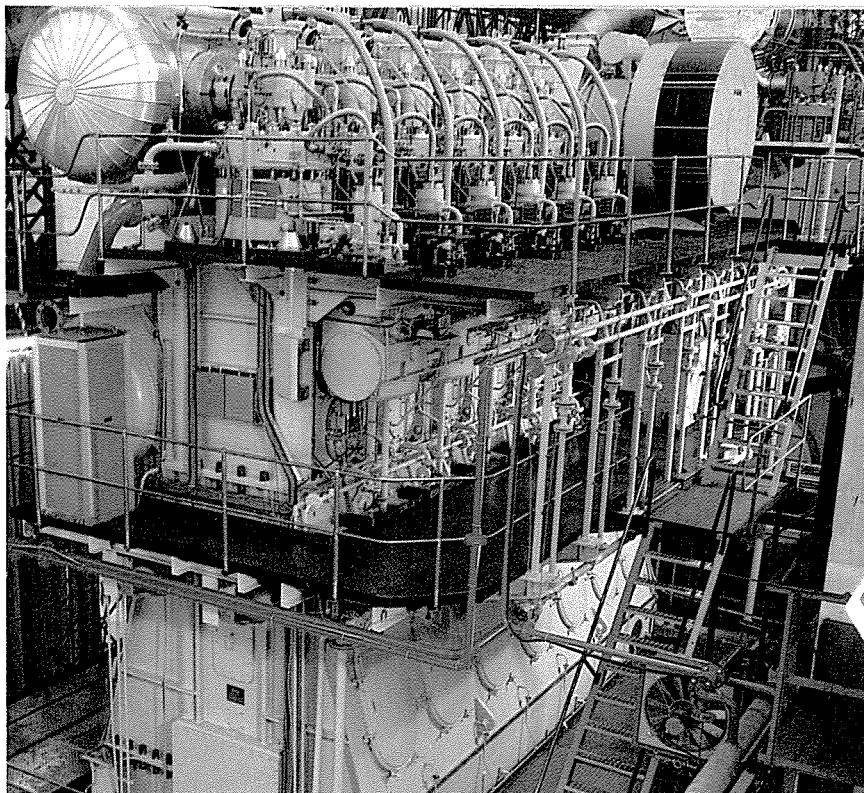
But big ships need big engines. Most economical is the two-stroke,

In the modern fighting ship, the engine room is small and cramped, but it performs a vital role. The engine must run for weeks on end so every function must be monitored constantly.



US Navy/TRH





enough to be connected directly to the propeller shaft. As long as the ship is not limited in draught by the terminals that it is designed to serve, the diesel's 30,000 or 40,000 horsepower will be applied to a single, large-diameter propeller. It may have four, five or six blades and turns at 70 to 100 revolutions per minute (rpm).

Reduction gearbox

An alternative is the four-stroke, medium speed diesel, which turns at between 250 and 750 rpm. It has a much lower profile and can be squeezed beneath the through car deck of a car ferry. Such a speed requires a reduction gearbox between engine and propeller. This can sometimes be used to reverse the ship but more frequently a controllable-pitch propeller is used.

Until the succession of 'oil crises' of the 1970s, nearly all large ships were steam-turbine powered. Quiet and vibration-free, the machinery was built integrally with the ship. Unfortunately,

slow speed diesel, often termed a 'cathedral' engine because of the way it towers three levels or more above its footplates. It is surrounded by successive decks, or 'flats', which accommodate the auxiliary machinery, like air compressors and receivers for starting and reversing the enormous engine.

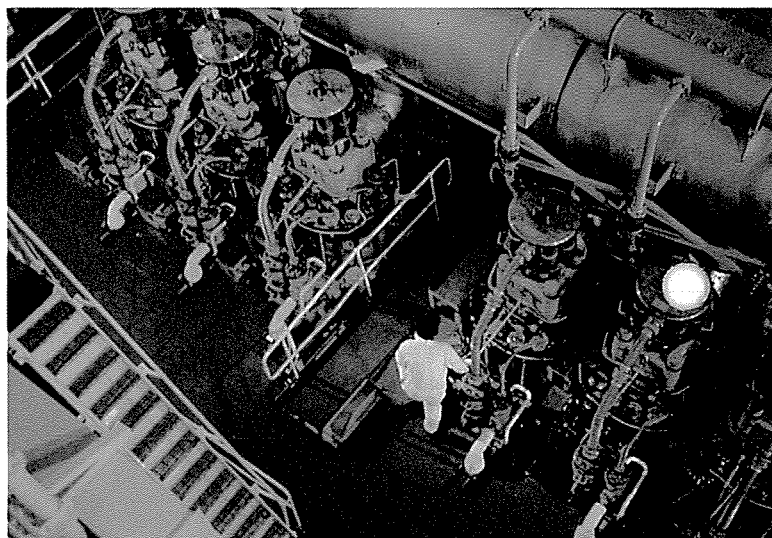
Unpumpable sludge

Diesel alternators provide the ship's electrical power. This is often enough to supply a small town. On an oil tanker a cargo-heating boiler prevents the massive cargo from solidifying into an unpumpable sludge. Also in the engine room are cargo pump turbines and evaporators which make fresh water for drinking.

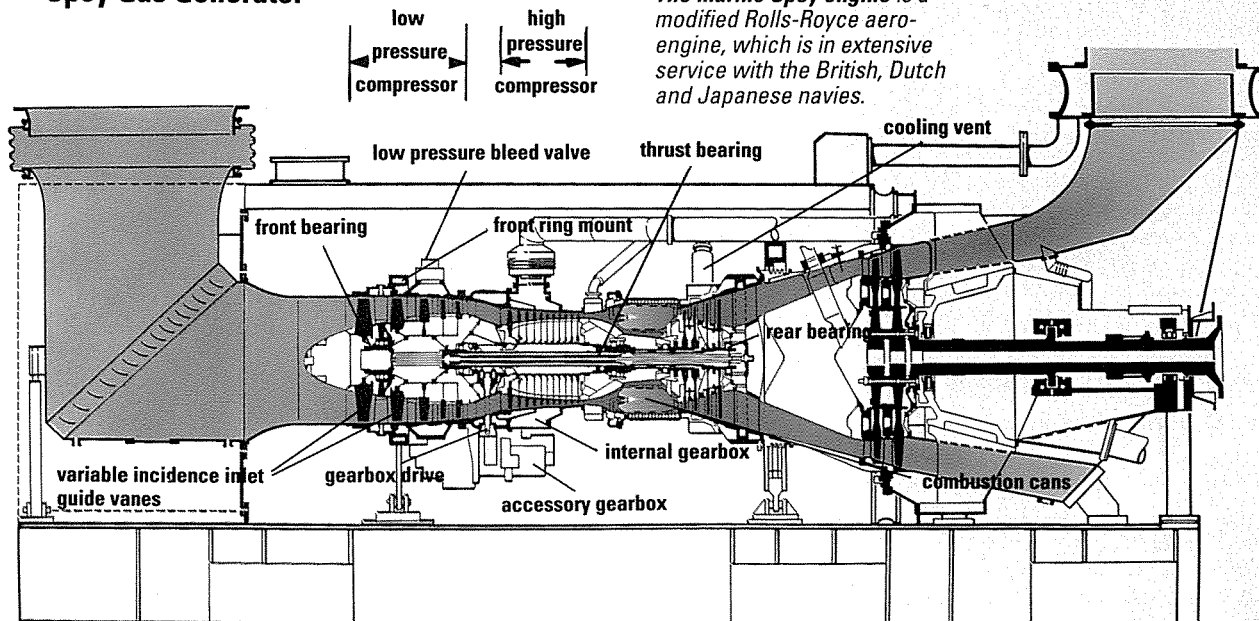
Cathedral engines run slowly

A 'cathedral' engine – a marine diesel two-stroke. This type of engine is used to propel an oil tanker, a bulk carrier or a container ship. Its fuel consumption is very low.

Huge tanker engines dwarf the men who work on them. Here an engineer is working beside the main engine of the MS Tribulus on its maiden voyage to Le Havre, France.



Spey Gas Generator



The marine Spey engine is a modified Rolls-Royce aero-engine, which is in extensive service with the British, Dutch and Japanese navies.

Shell

ENGINE REVOLUTION FOR THE NEW SUPER-FRIGATES

New types of ceramic, when kept very cold, conduct electricity with virtually no resistance losses. They are likely to revolutionize the motors used, among other things, for marine propulsion.

Small Waterplane Area, Twin Hull – or SWATH – frigates could feature a table-like deck, supported on two thin struts, which each stand on a submerged, torpedo-style hull. Like catamarans, SWATHs would have very little rocking motion, making them ideal for helicopter operations in rough weather. They could be propelled by superconducting electric motors, built into the submerged hulls.

US Naval Institute/DOD



steam plant needs more fuel than diesels. As fuel accounts for 25 per cent of the total operating costs of a quarter-million tonne tanker, and up to 40 per cent for a fast container ship, many steamships were scrapped. Others were converted to more efficient but slower diesel drive.

Electric motor

The most famous example of this was the liner *Queen Elizabeth 2*. In 1986, her steam turbines and boilers were ripped out to make way for nine great diesel alternators. Each of her two propeller shafts is now powered directly by an enormous electric motor.

Spare power is used to meet the demands of her passengers who expect the highest luxury standards.

But the steam turbine plant still survives in nuclear submarines. Heat generated in their reactors is transferred via a heat exchanger to a

closed cycle system which produces high pressure steam. This is used to drive a conventional turbine and, once spent, is condensed to pass around the system again.

Quick start

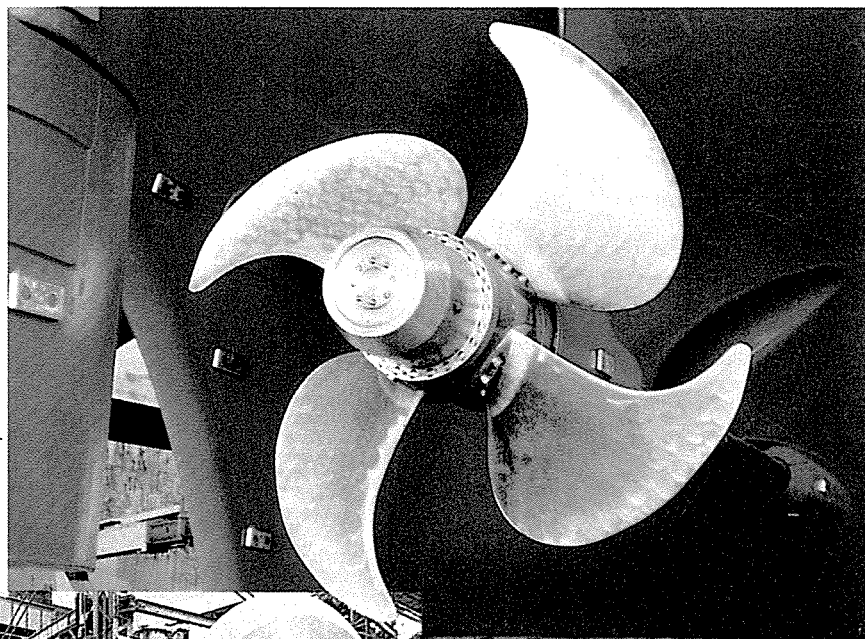
While merchant ships run most of the time at a constant 'service speed', warships need power reserves to accelerate rapidly to a high speed when required. It is also very useful to be able to start quickly 'from cold' without having to keep steam ready for use in the ship's boilers.

Warships now use gas turbines. Nought-to-thirty inside a minute may sound tame to a hot-car enthusiast

The Spey engine powers the fighting ships of several nations. It is a marine version of the aero-engine that powers the BAC 1-11 and the Fokker F28 aircraft.

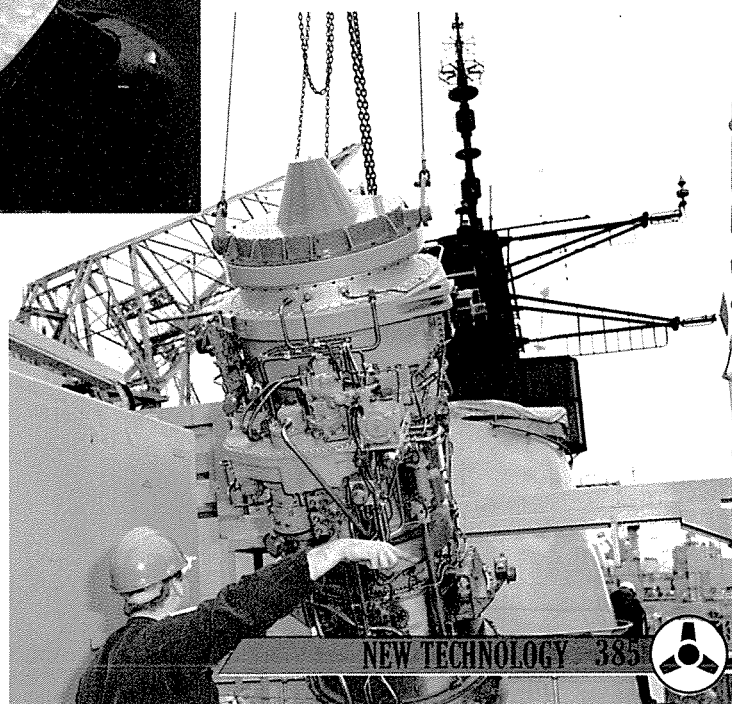
Mitsubishi Heavy Industries Ltd

Rolls Royce plc



Mitsubishi Heavy Industries Ltd

Marine engines drive propellers. This one is a variable pitch propeller, where the angle of the blades can be varied for maximum efficiency. For manoeuvring a huge tanker into port, a side thruster (left) is used.



NEW TECHNOLOGY 385



but it is very impressive for a 4,000-tonne destroyer. Straining ahead, her blowers whine, gulping tonnes of air to the hungry machinery. A thin plume of exhaust gas roars from the uptakes and a 'rooster tail' is thrown up astern as the propellers bite hard.



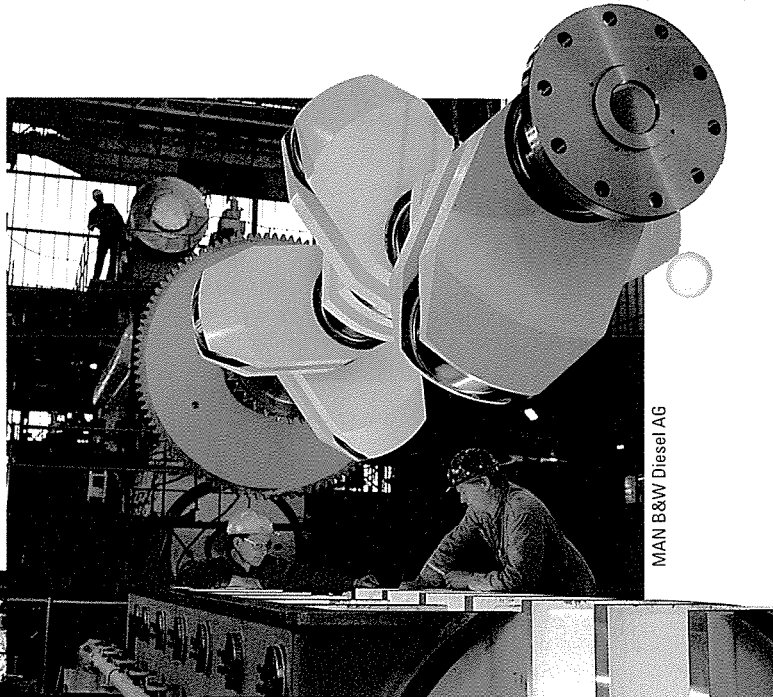
Overhaul

The marine gas turbine is derived from aero engines and is compact and powerful. When ships' engines need an overhaul, they are simply exchanged for new units. This can be done in a day or so, enabling the ship to return to service without delay.

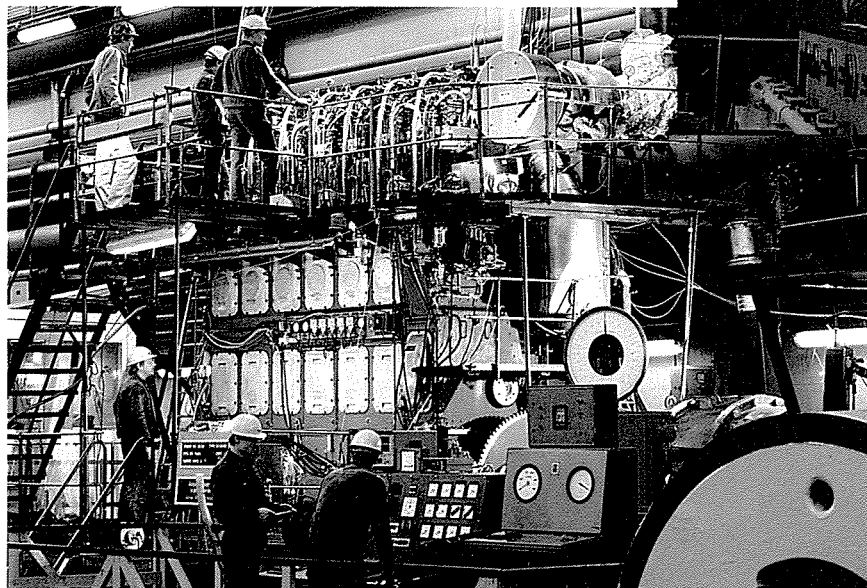
Unlike steam turbines, gas turbines are built only in a very small range of

The crankshaft of a huge two-stroke marine diesel engine being lowered gently to seat it in its main bearings.

Marine engines are rigorously tested before they are installed in a ship. Here a two-stroke diesel engine is put through its paces on a testbench.



MAN B&W Diesel AG



MAN B&W Diesel AG

standard units. They also burn expensive, refined fuel and work efficiently only near maximum speed. So it is necessary to combine the high power gas turbines for 'sprint' speeds with lower power machinery for cruising.

In the Royal Navy's latest frigates, the Type 23 'Duke' class, the need to silently stalk an enemy submarine has been made top priority with the designers. While she can speed along at 28 knots (51 km/h) on her gas turbines, a '23' can also creep quietly through the water with her

JET-POWERED SHIPS

Like aircraft, ships can be driven by jets rather than propellers. Some fast patrol boats achieve speeds of up to 50 knots (91 km/h) by riding on hydrofoils. These are underwater wings that lift the hull of the craft clear of the water, making driving a propeller difficult. Instead a gas turbine drives a water pump. This produces a powerful jet of water that propels the craft forward.

Japanese scientists hope eventually to achieve 100 knots (183 km/h) through electromagnetic propulsion. In their test vehicle, a water-filled duct runs the length of the hull. It is surrounded by powerful magnets. When special electrodes send an electric current through the water, it is expelled at high speed.

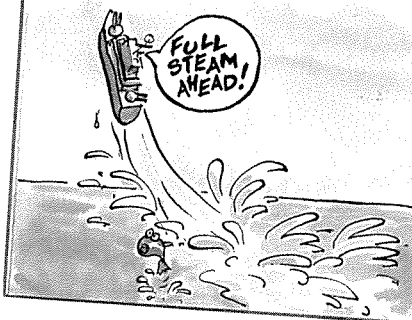
shafts turned electrically. The laws of hydrodynamics require that, while she needs to develop 37,000 horsepower (27,600 kW) for top speed, the 5,200 kW of the electric drive is still good for 16 knots (29 km/h)!

The huge piston of a marine engine being drilled out. The latest computer-controlled drills are used to ensure the greatest possible precision. Coolant is pumped down the drill bit and the swarf – or slivers of waste metal – is collected underneath.

Just amazing!

WE ARE SAILING/FLYING...!

THE ROYAL NAVY'S LATEST CLASS OF DESTROYERS ARE POWERED BY EXACTLY THE SAME ENGINES AS THOSE THAT POWER CONCORDE!



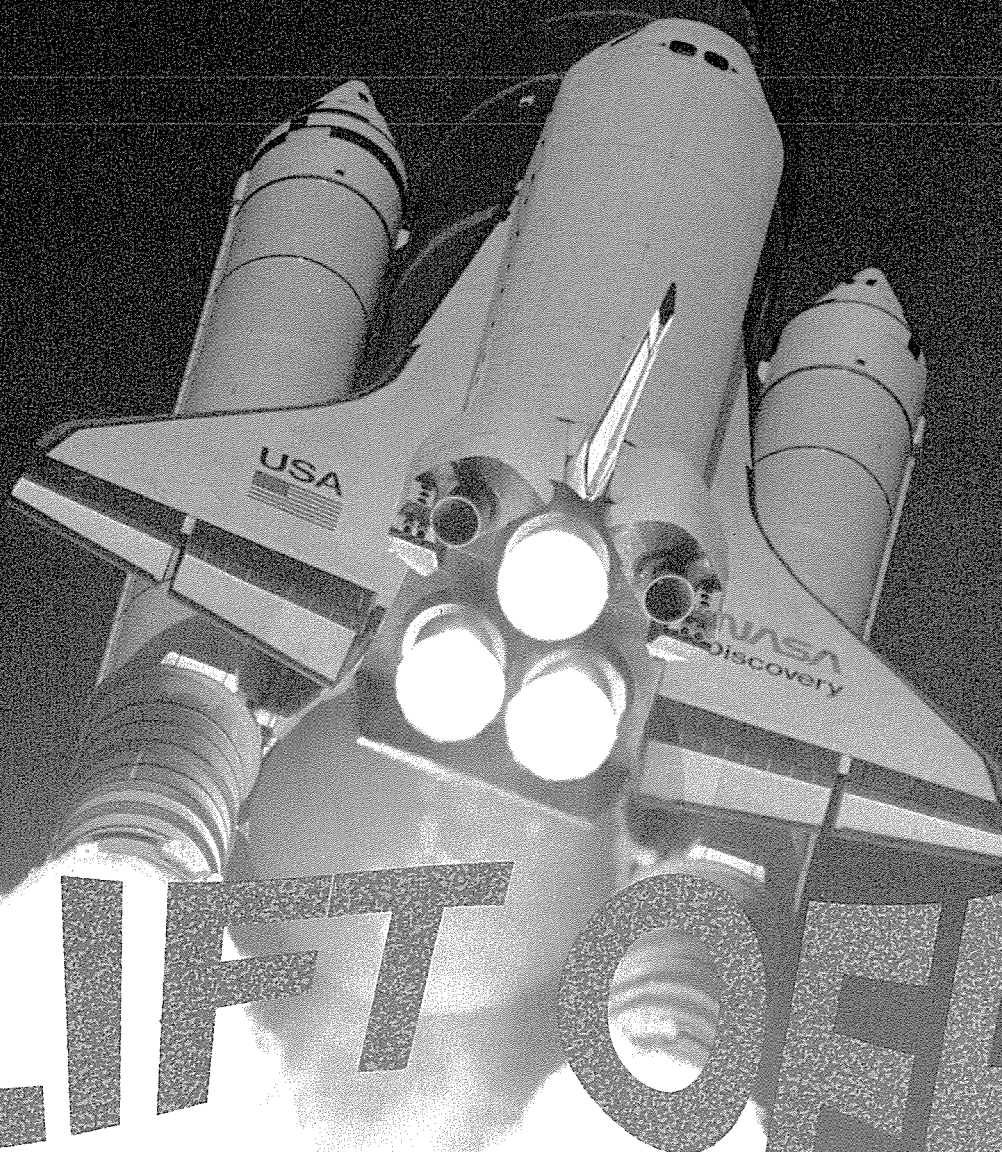
Paul Raymond



Q PREBURN

Q OXIDIZERS

Q STAGES



WATCH A ROCKET BLAST OFF and you get the impression that it is the thrust of its engines pushing against the air that propels it towards Space. But this is not the case.

All rockets work according to Isaac Newton's famous principle: 'for every action there is an equal and opposite reaction'. Imagine a shot putter wearing roller skates. As he throws the shot forward, he moves backwards. With the rocket, it is a case of 'throwing' its thrust backwards and moving forward. This action/reaction principle explains why rockets can still move in the airless vacuum of Space.



Controlled explosion

A rocket engine works rather like a very finely controlled explosion. Fuel burns with an oxidizer in a combustion chamber, and hot gas is created under great pressure. These gases accelerate out of the chamber and are made to accelerate even more because the outlet or throat is very small.

By controlling the outflow using a nozzle, even more thrust is created, as well as giving the rocket a basic guidance system.

In a typical rocket engine, small amounts of fuel and oxidizer are burned in a gas generator, which provides the power to operate turbopumps, which in turn are used to control the delivery of the fuel and oxidizer into the combustion chamber. At the same time, some of the fuel or oxidizer may be circulated around the engine and nozzle to provide cooling. The whole process has to be very carefully controlled. The wrong ratio of fuel and oxidizer could spell disaster.

The Space Shuttle's three main engines use a slightly different system that the gas generator cycle. The hydrogen and oxygen propellants are mixed and 'preburned' to create gases, which run the turbopumps. These inject the hot gases into the combustion chamber where an additional amount of oxidizer is

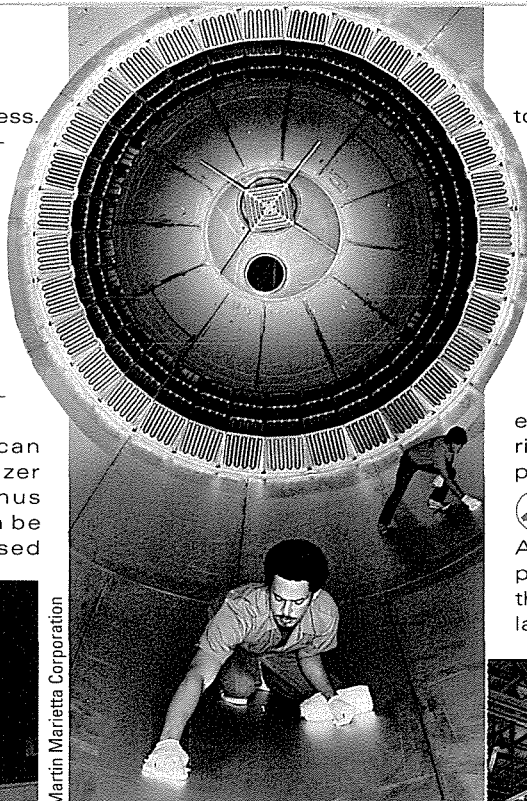
The Space Shuttle's engines are activated on the launch pad. The three main engines, attached to the orbiter itself, burn for 520 seconds. The strap-on boosters, which are later retrieved, burn for 120 seconds.



introduced to complete the process. This highly efficient method creates the highest thrust but it is more technically challenging.

Special materials have to be produced to withstand the enormous pressures and temperatures created in a rocket engine. A turbopump may have to generate 160 atmospheres to control the movement of the fuel into the chamber. It will be rotating at 34,000 rpm.

Combustion temperatures can reach 3,200°C. The liquid oxidizer and fuel can be as cold as minus 200°C. These propellants can be used for cooling by being passed



Martin Marietta Corporation

to geostationary transfer orbit with a minimum height (or perigee) of about 240 km and a maximum height (or apogee) of 36,000 km, the rocket is carefully guided along a preplanned path by the swivelling, or gimballing, of its engines and a laser gyroscope, which is used to control the computer guidance system.

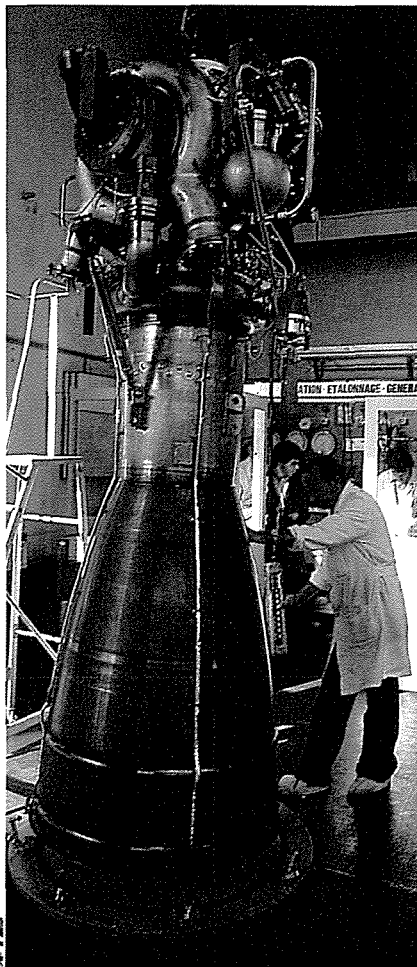
Special devices have to be attached to ensure the stages are explosively separated at exactly the right time without interfering with the precisely computed flight path.



Aerodynamic forces

A payload shroud, which has protected the satellite payload during the initial passage through the thicker layers of the atmosphere and the re-

Martin Marietta Corporation



Tom Haley/Rex Features

Three external tanks about to be transported to Kennedy Space Centre where they will be fitted to the Space Shuttle. Workers (above) apply the finishing touches to a liquid oxygen tank, a major component of the Shuttle's external tank.



through hundreds of tubes around the combustion chamber and nozzle.

There is no single rocket engine today that can carry a typical satellite into orbit all by itself. Satellites are therefore launched using a series of rockets either clustered together or stacked with their propellant tanks on top of one another in 'stages'.

During a typical 16-minute launch

sultant aerodynamic forces, will also be discarded en route to orbit.

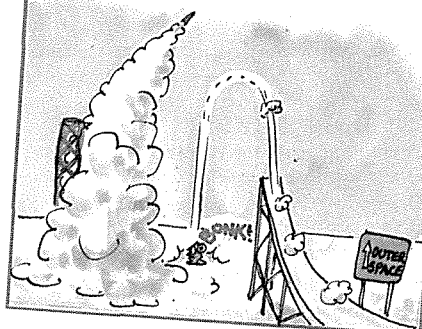
Rockets do not just differ in size, shape and number of engines but also in the type of propellants they use. The Ariane 44L first stage, strap-on boosters and second stage burn nitrogen tetroxide oxidizer and hydrazine fuel. These ignite as soon

Ariane rocket engines under construction in Vernon, France. The combustion chamber of the Ariane 5 Vulcaine engine is cooled by passing ultra-cold liquid hydrogen around 360 stainless steel tubes. The nozzle is cooled by passing liquid hydrogen through 456 tubes mounted on it.

Just amazing!

WHOOOSH!

THE ROCKET ATLAS SLV-3C LEFT EARTH AT AN UNPRECEDENTED SPEED OF 51,682 KM/H - 160 TIMES FASTER THAN THE WORLD'S FASTEST WHEEL-DRIVEN CAR.



Paul Raymond



Ariane 5's Vulcaine main rocket engine develops 110 tonnes of thrust and burns 25 tonnes of supercooled liquid hydrogen in the first ten minutes after launch.

as they come into contact, so no igniter is required in the combustion chamber. This fuel and oxidizer propellant mix is called hypergolic and its ignition has a peculiar high-pitched whining sound rather than the low rumble of some other engines.

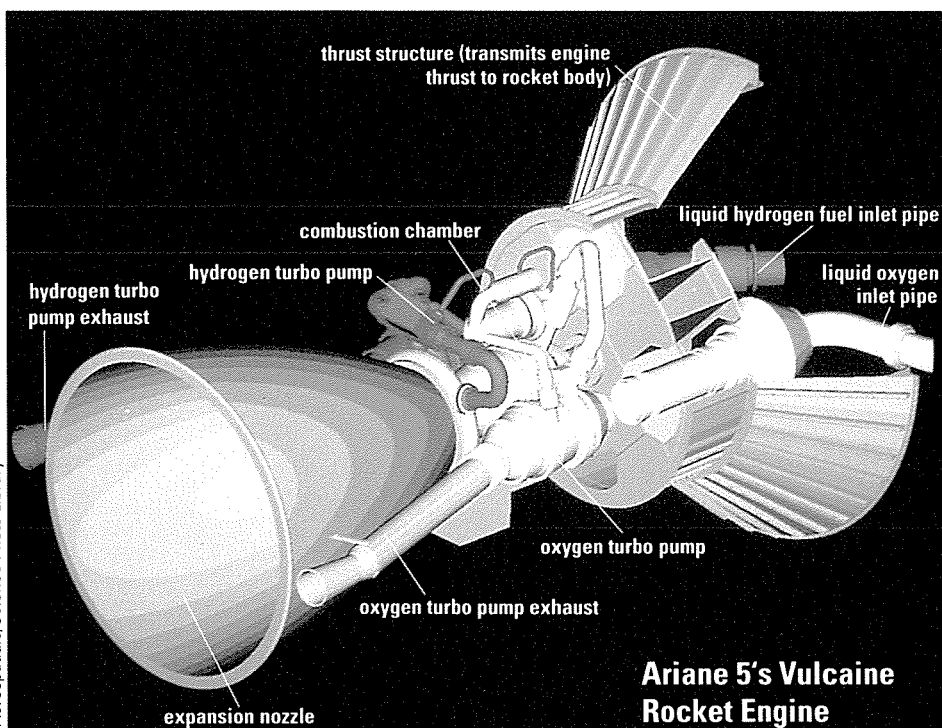
The liquid propellant of a rocket is stored in aluminium alloy tanks which, rather like aerosol cans, are designed to withstand pressure from within. These are mounted on top of each other above the engines, within the walls of the booster stage.



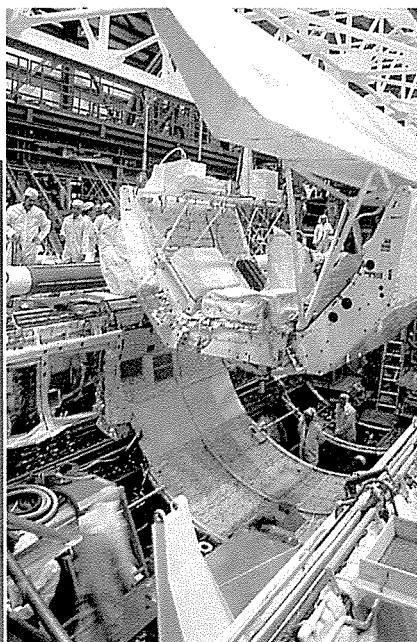
Cryogenic oxygen

The Ariane third stage uses ultra-cold, or cryogenic, liquid gases, liquid oxygen (oxidizer) and liquid hydrogen (fuel). The Space Shuttle main engines also use these propellants but the strap-on boosters use a solid propellant, which looks rather like the material in a pencil eraser. This is a mixture of aluminium powder, ammonium perchlorate, iron oxide and a binder and curing agent.

The propellant is carefully mixed and the inside of the booster is lined



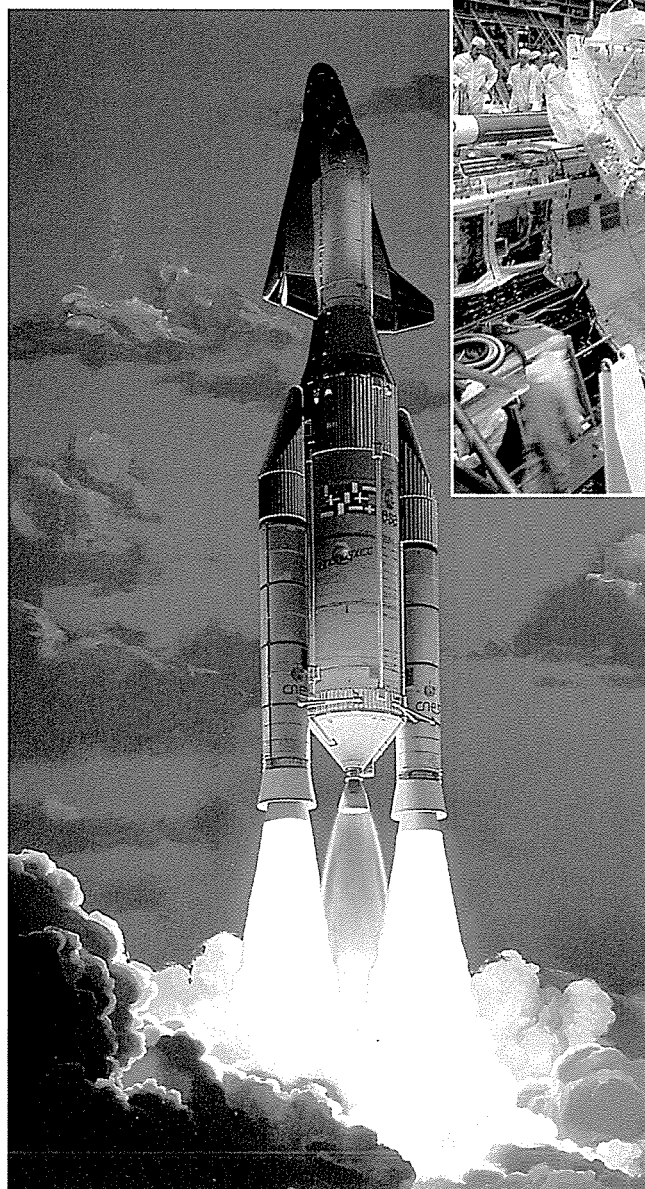
Ariane 5's Vulcaine Rocket Engine



with it. To make the lining process easier, the booster is assembled in segments and joined together. The jointing of the segments is very important, because a mistake can lead to the escape of gases through the joint rather than the nozzle. Just such an escape was responsible for the *Challenger* Shuttle disaster in 1986.

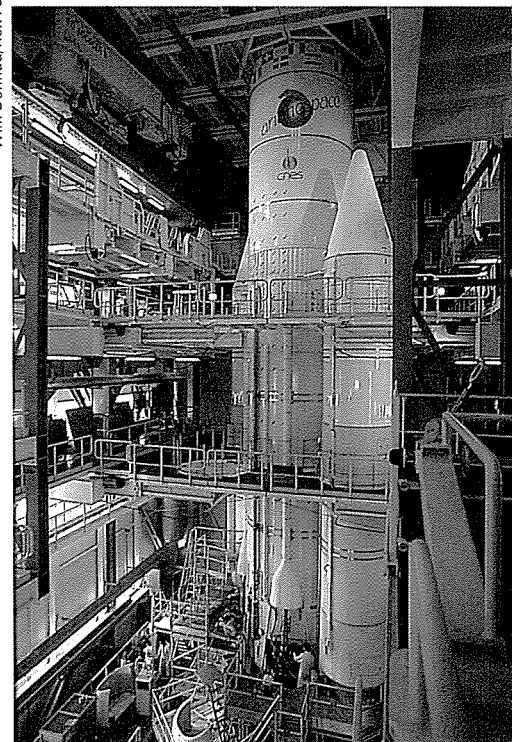
Once assembled, the tube-like booster is lined with its propellant in such a way that it is thickest at the top and tapers to a thin layer towards the end. The igniter is at the top and, as the fuel burns, the hot exhaust passes down the hollow interior of the booster between the propellant and finally out of the specially shaped nozzle.

L Maons/Gamma/Frank Spooner Pictures



Manchil/Jerrican

Ariane 5's giant rocket boosters will lift the spacecraft Hermes (seen under construction above) into Space. Ariane 44L, (right) the world's most powerful commercially operated satellite launcher, has a combination of 10 engines.



Wim Donau/Rex Features





VIEW

ON THE TRACKS



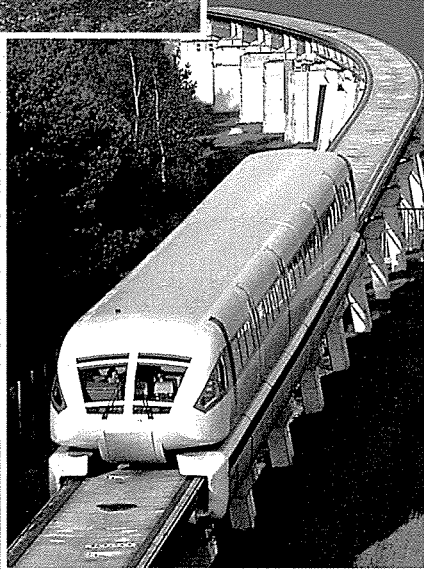
Steam locomotives are still used to transport freight in many parts of the world. This old-style locomotive is used for shunting in the Shanxi region of China.

M. Carrington/Quadrant

Corey/Schilling/Rex Features

The advanced passenger train (APT) project was abandoned due to technical problems with its cornering-tilting mechanism.

Goebel/ZEFA



The Transrapid, a passenger system under development in Germany, runs on a system of electromagnetic levitation called Maglev.

Trains that travel through mountainous regions have gears fitted to them to help increase the wheels' gripping power.

C. Dixon/Rex Features

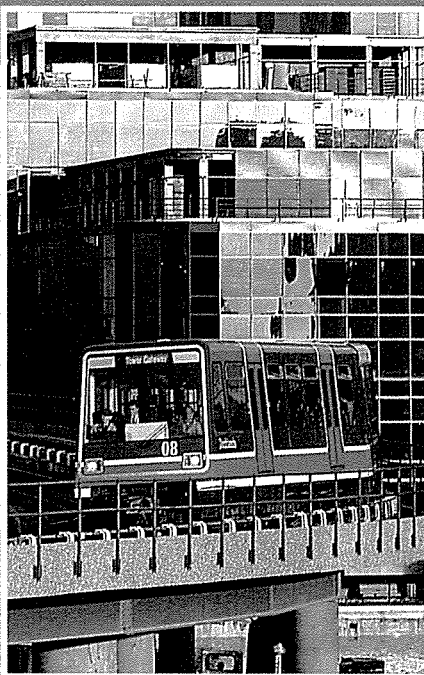
H. Ballantyne/ZEFA



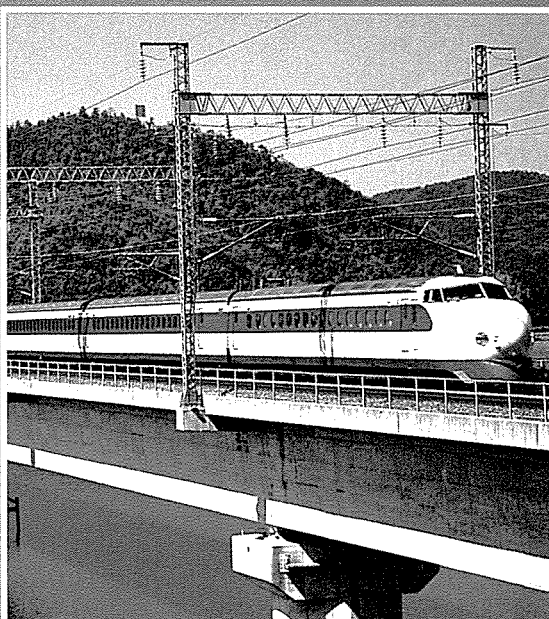
Union Pacific freight engines (diesel-electric locomotives) are 29 metres long and weigh 229 tonnes.

France's TGV trains (Train à Grande Vitesse) are driven by two power cars, each with six 524 kW motors.

Quadrant



Orion Press/ZEFA



Trains on the Docklands Light Railway in London are driven by a computerized 'automatic train protection system'.

Japan's Shinkansen (bullet) trains can accelerate extremely rapidly because each axle has its own motor.



Danmarks/Jardian

NEWS FLASH

Thanks to Electronic News Gathering, world events, such as the breaching of the Berlin Wall, can now be followed by an audience of billions.

RECENTLY, THE DREAM OF broadcasting news events as and when they happen throughout the world has become a reality. Television viewers have been able to share the apprehension of Chinese students demonstrating in Tiananmen Square and join in the excitement as the happy crowds celebrated the demise of the Berlin Wall.

That these live events have been viewed, not just by selected Western audiences but throughout the world, is due to the enormous advances made in Electronic News Gathering (ENG). Traditionally, the news from all over the world has been gathered by on-the-spot reporters. They would either send their stories by telex or telephone as a written report, which would then be edited and read by the TV news reader, or they would talk to the camera in a filmed report. The film or videotape would then be sent back to the studio by land or air and, where

the area is particularly remote, this might take a very long time.

Nowadays, with the aid of a network of communications satellites, and a battery of other new technology, news teams can broadcast direct from the places where news events are happening – recording events that affect the world as they actually take place. Any event can be covered directly. The only time lag is how long it takes to get the news team and their

Time for the news bulletin at the CNN studio in Atlanta – using five transponders for transmission, the agency broadcasts to 95 nations.

recording equipment in position.

At the forefront of the development of ENG and the global news service is the American company, Cable News Network (CNN), founded by Ted Turner in 1980. What Turner



CNN





Direct news broadcasting made easy. Today, ENG crews rely on the latest state-of-the-art camera and sound equipment linked up with satellites, providing the opportunity of on-the-spot broadcasting from all over the world.

work who then tell them which satellite is broadcasting the news. The programmes are usually broadcast in English, although some subscribers add subtitles or translations. As the signal from the satellite is not scrambled, in theory anyone with a TV set and satellite receiver can find it – especially in areas like Africa and the Middle East where the airwaves are less crowded.

Celebrity TV

When it first started, the network was criticized as television's equivalent of tabloid journalism. Now, however, it has enormous status not only among the viewing public but also among newsmakers themselves. Many American politicians will delay their press conferences if CNN crews are not present.

© BBC foresaw and developed was a service to television stations which was the equivalent of that given by news agencies to the written press. CNN takes in news stories from around the world 24 hours a day and redistributes them at the same time.

Turner's genius was to foresee the

TRANSPONDERS

The main task of communications satellites is carried out by a number of transponders. These are a combination of a receiver and transmitter. The receiver collects the carrier signal being transmitted from Earth and then amplifies it before changing its frequency. This information is then transferred to another carrier signal on a different frequency and amplified once more before being transmitted back down to Earth via an antenna.

The transponder acts as the satellite equivalent of an open telephone line. There are satellite agencies which lease transponders to news agencies and this equipment is generally in use for 24 hours a day. CNN needs five transponders just to transmit the signal out of its home base in Atlanta, Georgia, in the United States. Each one costs one million dollars a year for 24-hour transmission, but many other stations are willing to pay for the service.



CNN

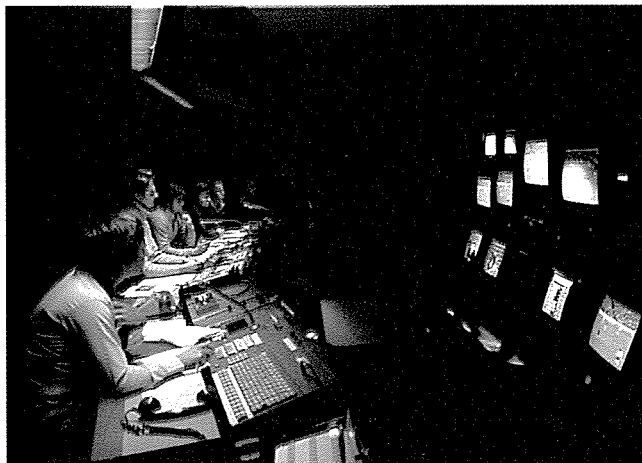
growing appetite for global news and to harness increasingly sophisticated satellite technology to convey the news. When Turner started his network, its main aim was to distribute news via satellite to the new cable television stations around the continental United States. Soon he was also providing world news via satellite to Japanese broadcasters.

CNN now broadcasts to 95 nations throughout the world including China and Australia. Besides being received and rebroadcast by various television stations worldwide, CNN's news broadcasts are also bought by international companies, hotels and embassies worldwide. They pay an annual subscription rate to the net-

In CNN's large newsroom, news is monitored and prepared for redistribution to a long list of subscribers. At the BBC's morning conference (below), editors decide which news items are going to be covered.



The studio gallery is the nerve centre of the TV newsroom. Here, items are closely monitored by controllers who can interrupt the proceedings by inserting the latest news flash.



Other world leaders are equally keen. The list of those receiving CNN in their offices includes Mr Gorbachev, Francois Mitterand, King Fahd and Fidel Castro. Before the Gulf war both President Bush and President Saddam of Iraq watched CNN to look out for shifts in each other's policy. It is also reported that President Izal of Turkey was watching a live CNN interview with Bush early in the Gulf Crisis when the US President concluded the interview by saying he had to call the Turkish president. As Mr Izal turned from the television to his desk, the phone was already ringing.

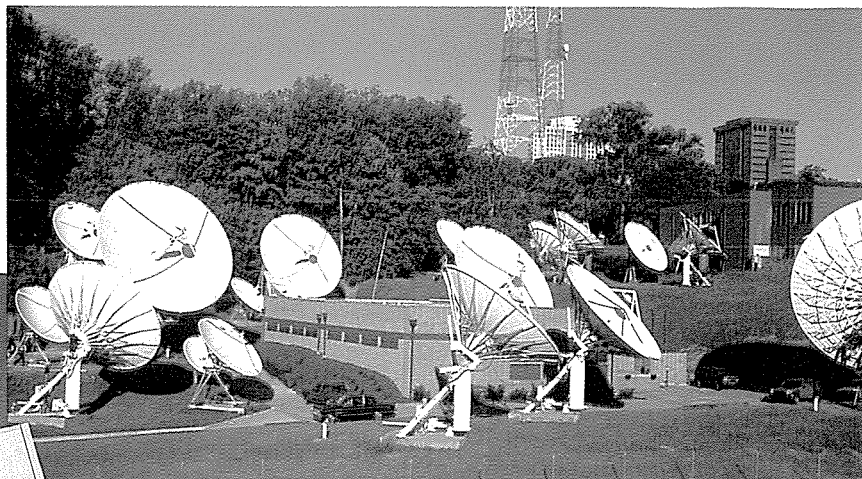
CNN's advantage over the other more established television networks is the fact that its primary focus is journalism. On other stations it is entertainment. This means that CNN can explore news items in depth and give them an international context. Furthermore, CNN does not suffer

© BBC

© BBC

from any lack of action footage.

The spread of cable also means that CNN is available to a massive audience of 55 million cable subscribers in the USA and over 14 million outside it. Even though only a small percentage are watching at most times, this potential audience has an enormous impact. CNN has become the closest thing yet to the 'global vil-



CNN

Outside broadcast units act as a mobile satellite ground station. The dish aerials (which can be stowed away in transit) are used to beam the signals to a satellite in orbit. Dish antennas on the ground (above) then pick up the 'hot news'.

vision channel; and ABC and CBS have links with major Japanese television networks.

Nowadays, live coverage of an event is essential. Only by combining resources and sharing technology can national networks hope to reduce the cost of global news gathering and maintain their share of the audience.

Receiving the news

Over the past few years television crews have been on hand to record some crucial moments in history. One of the most stunning was the almost immediate transmission of the events of China's 1989 student revolution

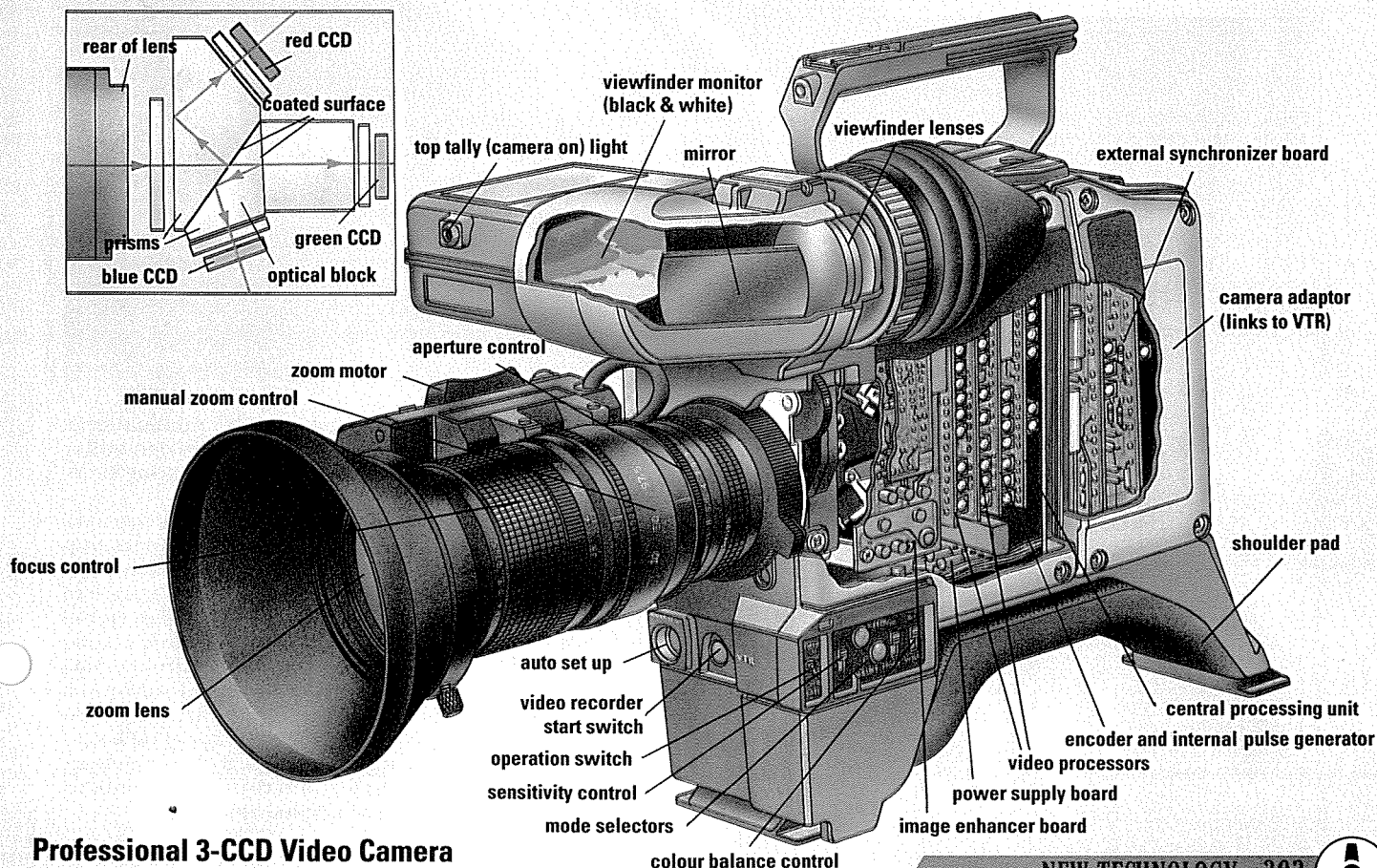
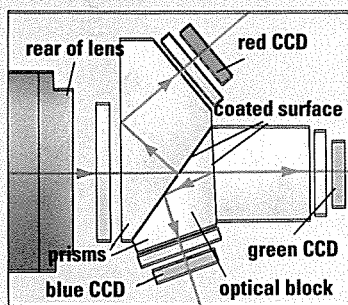
lage' which media experts have for so long forecast.

Other television networks cannot compete with Turner's giant organization and worldwide income. However, the major American television stations - NBC, ABC and CBS - have all installed link-ups

with several foreign news services. NBC News bought 37.5 per cent of the London-based video news service Visnews; ABC News raised its stake from 45 to 80 per cent in the similar Worldwide Television News; the BBC has extended its highly regarded radio World Service to include a tele-

Professional ENG video cameras today have a solid-state interior featuring three CCDs (Charge Coupled Devices) for the three primary colours.

Trevor Hill



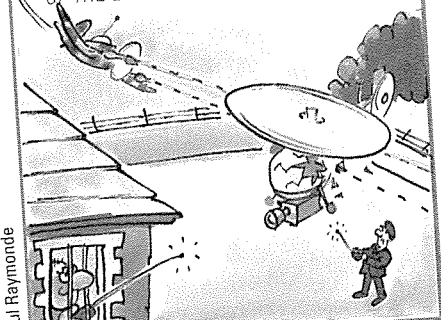
Professional 3-CCD Video Camera



Just amazing!

EYE IN THE SKY

DURING A STRANGWAYS PRISON SIEGE, THE ENG CREW USED A MINIATURE HELICOPTER CALLED 'HAWKEYE' TO GET AN INSIDER'S VIEW OF THE EVENTS.



and its savage crushing. Even when the Chinese authorities closed down their satellite ground stations, making direct transmission impossible, film of the revolt still got out.

Direct sound

A senior BBC news editor smuggled some videotapes out of his hotel hidden in his underpants, and other crews used equally unorthodox means to get their footage to the airport. From there couriers flew the tapes to Hong Kong or Tokyo for immediate transmission to the rest of the world. Satellites were still useful for direct sound broadcasts. One BBC reporter hired a local taxi fitted with a radio telephone and used it to relay di-

rect broadcasts from Tiananmen Square in Beijing.

Other notable direct broadcasts include the *Challenger* Space Shuttle disaster, the US invasion of Panama, Eastern Europe's emergence from Russian domination and the opening of the Berlin Wall. These events, and many more, have been broadcast live into the homes and offices of millions of people around the world.

Satellite links

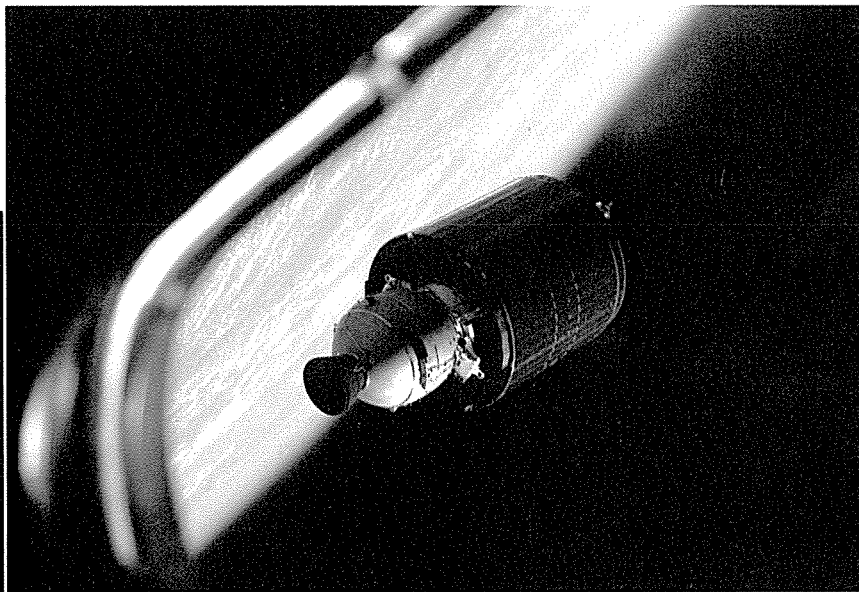
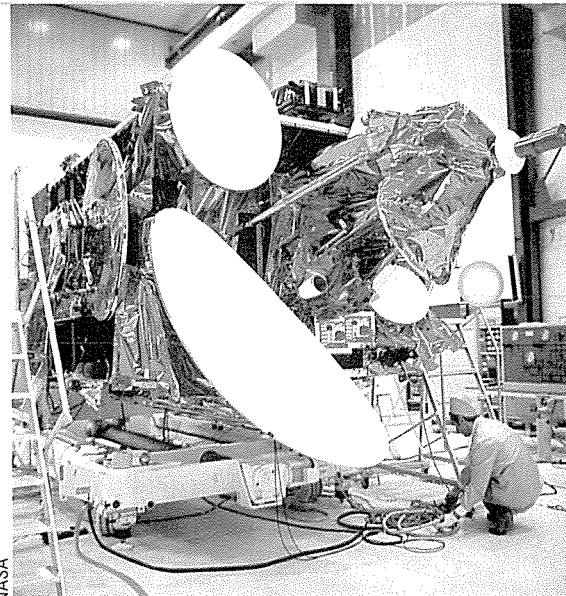
Just as they use communications satellites to transmit television sound and vision signals, television news networks use satellites to receive signals from ground or Earth stations. Signals are received or transmitted from Earth by dish-shaped antennas, which contain equipment to process the signals. These are received and re-transmitted by the antenna (although not always dish-shaped) of the communications satellite.

While a signal can be sent direct into any country without the permission of its government, most news organizations need permission from host countries to transmit signals to the satellite. The price of this, together with the leasing fees paid to the international satellite agency, Intelsat, cost agencies like CNN up to US\$100,000 a week per country.

On the ground, the most recent

A communications satellite is prepared for its launch into geostationary orbit. It will act as a relay station, transmitting data to and from ground stations.

technological innovations are the mobile ENG units which can transmit signals from specially equipped trucks direct to the satellite without the need to use any ground-based systems. The Starbird Satellite Services division of London-based WTN operates a fleet of such trucks in the UK and Europe in partnership with

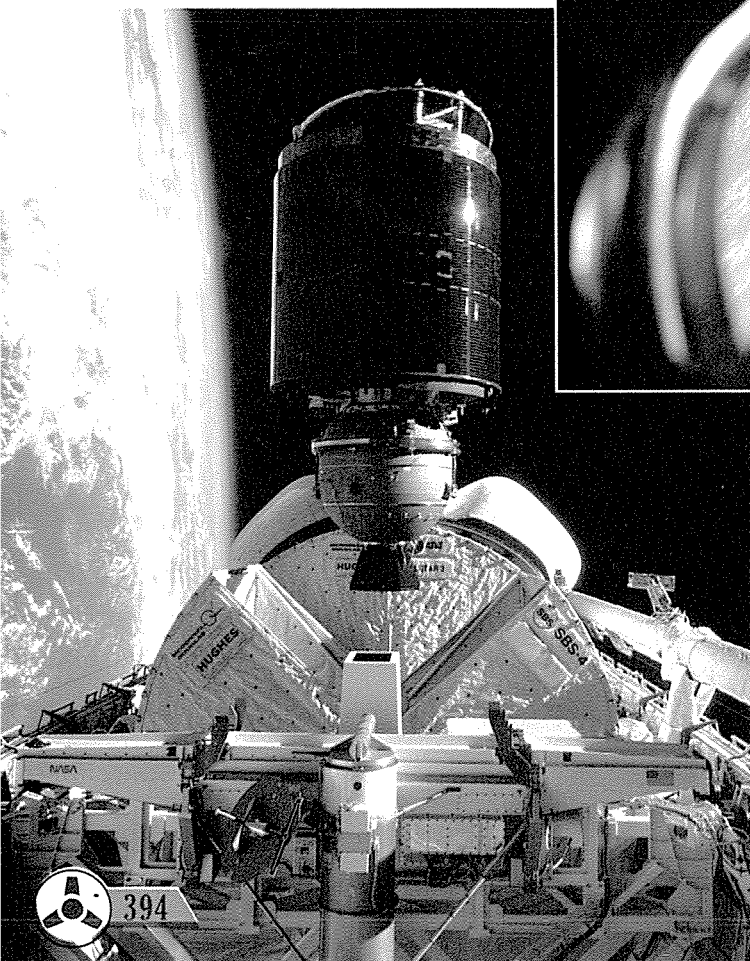


ESA/Science Photo Library

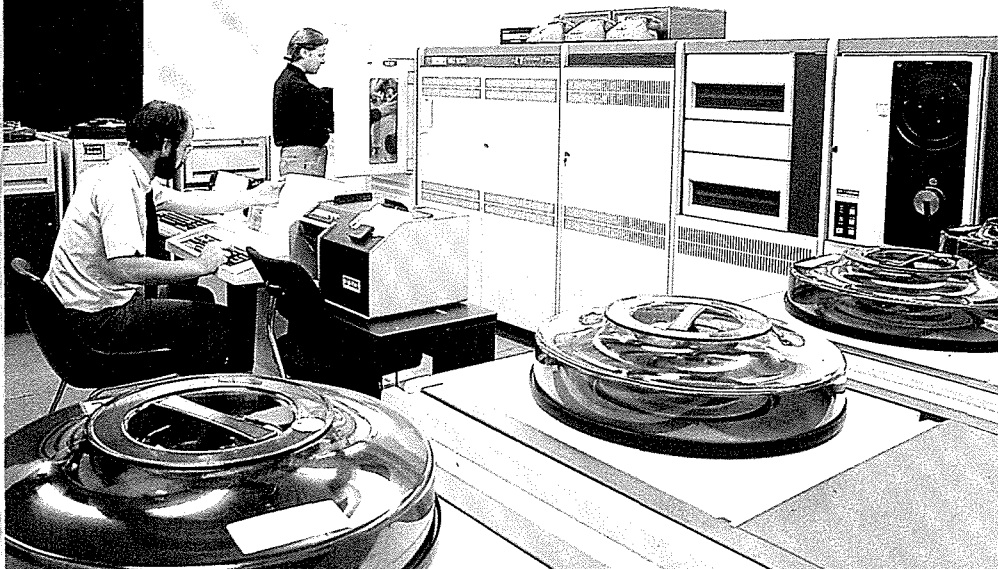
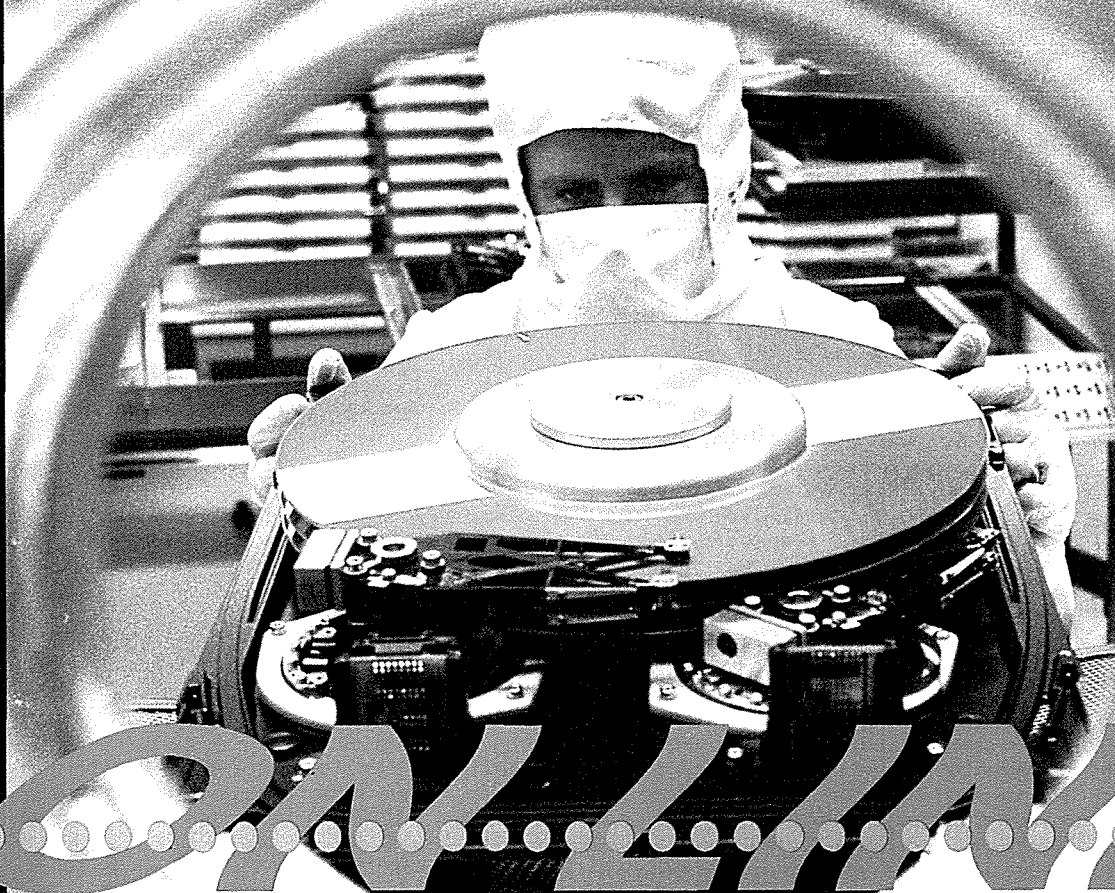
Leaving its protective shield, the SBS-4 communications satellite spins and rises from Space Shuttle Discovery to begin life in Space. After its launch from Challenger, the Canadian satellite Anik C2 (above) carried out a number of manoeuvres to get into orbit.

British Aerospace Communications. On-the-spot news editors can either broadcast live or edit material for instant transmission.

The same basic facilities are also provided for transportation to anywhere in the world and are similar to CNN's 'flyaway' - a portable satellite link-up that can provide a live signal from previously inaccessible places within hours. The WTN Starbird satellite dish placed on top of Amman's Intercontinental Hotel attracted the business of countless other news organizations anxious to transmit their coverage of the Gulf Crisis back to their various home stations.



394



IBM

A technician inspects a hard disc unit—heart of an online database—in a 'clean' room during manufacture.

Banks of hard disc machines store data while the power of a large computer makes it available online to remote users.

Digital **A WRITER FACING A DEADLINE** has to provide a topical article but needs a crucial piece of information that appeared in a newspaper a few years back. A certain John Doe was involved in a legal battle with a firm called Smith & Son. But when was it, which paper was it in and what was the verdict?

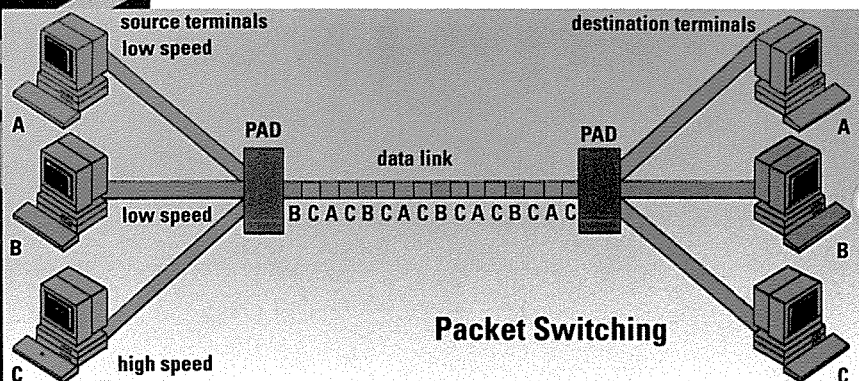
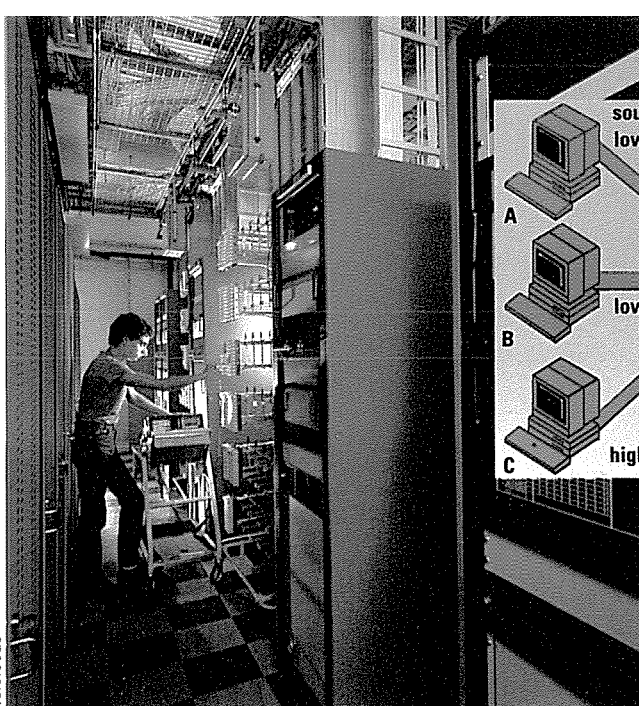
It would take ages to go down to the library and search the back numbers of the newspapers, but fortunately there is an alternative.

Going online

The writer can turn to a modem and phone and dial a number. A few keystrokes and he or she will be connected to an online database, which

contains the entire texts of major newspapers and business magazines. The next step is to select a newspaper and type in 'John Doe + Smith'. The screen says '15 items found'. 'Pick verdict' isolates only the two articles which include the words 'John Doe', 'Smith' and 'verdict'. Another keystroke displays their headlines. The next brings up the full text of the





Packet-switching equipment (left) has **packet assembler/disassemblers (PADs)** to combine or separate data streams of varying speeds.

people, whether criminals, terrorists or simply ordinary citizens. It is when this is combined with other innocent information, a technique known as **profiling**, that problems can arise. For example, a person may subscribe to a rifle magazine because they are keen on target shooting, and may also be a member of an environmental group noted for its dramatic exploits. Should that person be recorded heading for a town on the day of an expected demonstration, a computer may send out an automatic alert that he or she is

Mark Franklin

relevant piece. This appears rapidly on the screen and is saved. The writer then logs off after being charged for just three minutes connection time.

Online databases are not cheap to use – with the same money, the writer could have bought enough petrol for 100 km of driving. But time is money, and the real saving is half a day of time. To search the newspapers by hand is very time-consuming, and often the indexes are not very detailed. The great advantage of online databases is they provide the power of a large computer to the user of the simplest equipment. This can

formation – the car was stolen earlier in the day. Within minutes, the suspect has been arrested.

Profiling

No-one, except the criminal, would object to this use of a database. But the problems arise when the car-number database is combined with other equally innocent information that may be stored about people. Systems are available which can automatically read the numbers of all cars travelling along a motorway. Computer power could then be used to build up a complete picture of the movements of

MESSAGES BY FROG

One of the problems of sending data over phone wires is the danger of transmission errors. Line noise – clicks or interference on the line – can corrupt the information, perhaps with dire results since the error may not be obvious. So there are various error correction techniques, such as using check sums. A number is added during transmission to the one being sent, so as to give the same total each time. If the received figures do not add up properly, the number is sent again till they do. One popular program for doing this is called Kermit – named by its inventor, Frank da Cruz of Columbia University, New York, after the green frog on the Muppet Show.

A French policeman uses an online mobile computer with his own 'smart card' to check a suspect's identity details.

Operators at this control centre at New Scotland Yard receive police requests for information from all over the UK and can go online to a range of computers.



Metropolitan Police

also be their greatest drawback and the reason why civil liberties groups view the increasing computerization of our society with some suspicion.

The police are using databases to an increasing extent. A police officer may be called to the scene of a minor car accident, but has his or her suspicions aroused by the behaviour of one of the drivers who seems anxious to avoid trouble. The officer radios the driver's car number to a control centre, who immediately tap it into their terminal, connected to the police car number records. Back comes the in-

by splitting their data up into small electronic packets, each with a specific address and its place in the sequence. These packets are then interleaved with others, each with their own destinations. At the far end the packets are re-assembled and sent on to their destinations in the right order.

It is possible for hundreds of data streams to be combined in this way. The control computers constantly seek the best route for the packets, and a particular message may travel by different routes, which can vary thousands of times a second.

The whole system is the electronic equivalent of ordinary mail service, where individually addressed packets are collected and sent in bulk to be sorted out at their destination. Each mail van carries packets for many different destinations, and different packets from one sender to the same address may travel in different vans.

The cost of using the packet-switched network is shared between all users, just as it is cheaper to send a letter by ordinary mail service than to use a courier.

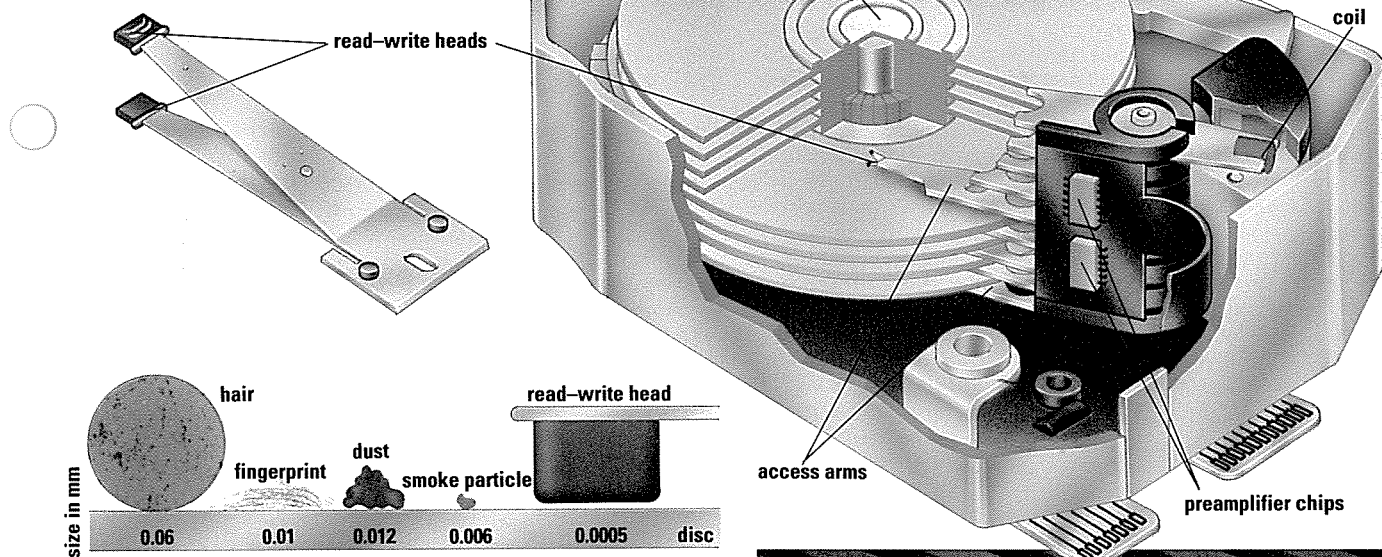
The Starlink network allows UK astronomers to share data and software. Images can be altered to show more detail (inset).

Science Photo Library

a potential troublemaker who should be arrested at the first sign of trouble.

It is common these days for people to use databases in other countries without even being aware of it. A business secretary can call up an airline schedule database to work out a complicated itinerary and check whether seats are still available. The computer itself is in Illinois, USA, but the connection is made instantly, wherever in the world the secretary may be. Yet the

'Winchester' Hard Disc Storage



Mark Franklin

cost of using the database is little more than that of phoning up the recorded local weather forecast or sports scores, even though the secretary seems to have full access to the database for minutes on end. This is possible through a technique known as packet switching.

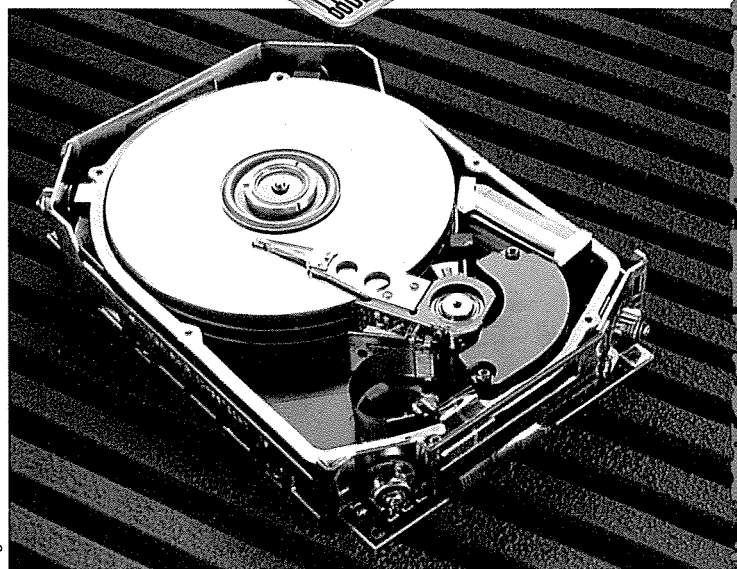


Packet switching

In addition to the regular telephone lines which extend round the world, there is now a separate data-carrying network of circuits suited to high-speed data transmission. But these circuits are expensive to maintain, and it would not be practical to let individuals use them for long periods of time. This is where the packet-switching system is used. It enables many people to use the same data line at once,

'Winchester' type hard disc devices are used for data storage. They have several magnetic discs spinning at 3,600 rpm and read-write heads to record the data.

The clearance between head and disc is equivalent to a jumbo jet flying 1 cm above ground, and any particles of smoke or dust can destroy the head. Capacity of a disc unit (right) is 400 megabytes – a big encyclopædia.



In this way, the cost of using a database overseas is less than holding a conversation with someone.

The range of services available through databases is increasing all the time. Many professions now have their own databases, particularly for information which needs to be kept continually up-to-date.

CD-ROMs

Bookshops, for example, have instant access to the catalogue of books in print. Again, the power of a computer is invaluable: if a customer asks about a book that is something to do with fishing, by someone called Hartman or was it Hartwell, the operator need only type in 'fishing' under title and 'Hart*' under author. The computer will search all books with 'fishing' in the title and locate the one which has the four letters 'Hart...' as part of the author's name, to come up with 'Fly Fishing' by J R Hartley.

Online systems such as this are in direct competition with other storage methods, such as CD-ROMs. These are compact discs, which carry whole

books and encyclopædies. Once the user has bought the hardware to read them, they can then buy discs which offer a wide range of information. Their advantage is that they can include colour illustrations and even video

France Telecom

Five million French phone users have Minitel terminals which allow them to use over 10,000 services, including games (top). The keyboards are easy to use – to connect you dial a number and press a key. Menus of services then appear.

sequences with stereo sound, but the drawback is that, as with books, they become out of date and are expensive to buy for occasional use.

Online databases can often be accessed through electronic mail systems, which send messages direct from one computer to another. E-mail has the potential to replace much ordinary mail, but it is still little used compared with postal systems, telex and fax. E-mail has several advantages – it can be very cheap to send messages, they arrive virtually instantly, and they are already in text form, so they can be stored on disc very conveniently. It is also a good way to convert computer files from one disc format to another – everything is sent as standard ASCII (American Standard Code for Information Interchange) characters, so users can have virtually any computer they choose.

Revolution

But the increasing popularity of Internet and e-mail is clear. A researcher in Edinburgh can easily send a message to a colleague in Australia or Chile since all the university networks are linked by 'gateways' between them.

For scientists this has particular advantages. They can exchange software very easily, saving a great deal of time when it comes to analysing what their data tell them. No longer need each department keep a huge library of software or data.

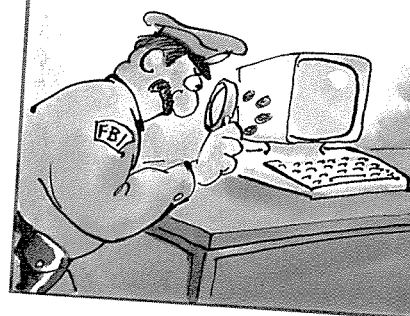
For years, experts have been predicting that every home will soon have a computer, and that everyone will be communicating by e-mail. Until recently, however, while many people had home computers very few of them bothered to join e-mail systems. Those that now join have access to a vast range of services, such as home banking and ordering some goods thank to Internet, but in most countries the electronic revolution has yet to arrive.

Gaillard/Jerrican

Just amazing!

KEEPING DABS

THE FBI USES COMPUTERS TO STORE MORE THAN 20,000 NEW SETS OF FINGERPRINTS EVERY DAY – OVER 7 MILLION FINGERPRINTS A YEAR.



Paul Raymond

DIY POST OFFICE

Many computer enthusiasts set up their own online services, often free of charge. All that's needed is a computer with sufficient storage, suitable software and a modem permanently connected to a phone line. These services are often bulletin boards, where people can leave messages for all to see, but they can also offer private e-mail that can be read only by the person it's meant for. Hobby groups, such as astronomers and bird-watchers, run their own bulletin boards with material of interest to members, so that the latest information can be spread instantly. The only drawback is that bulletin boards can unwittingly pass on software infected by a computer virus.

With the online airline guide you can plan your flight schedule around the world from your desktop computer.

Official Airline Guides

• SKIMMING THE WAVES

EVERY SHIP, FROM A SMALL yacht to the largest supertanker, must displace its own weight of water to float steadily. To move ahead, it has to shoulder aside this displaced water and, in the case of a loaded supertanker weighing about half a million tonnes, powerful engines are needed to do the job.

In order to improve speed from 15 knots to 20, a large typical 'displacement hull' would need to raise its output from 3,000 to 8,000 horsepower (hp). An increase of just another five knots would require

20,000 hp (14,920 kW)! This problem facing all naval architects is due mainly to water resistance or drag.

Making waves

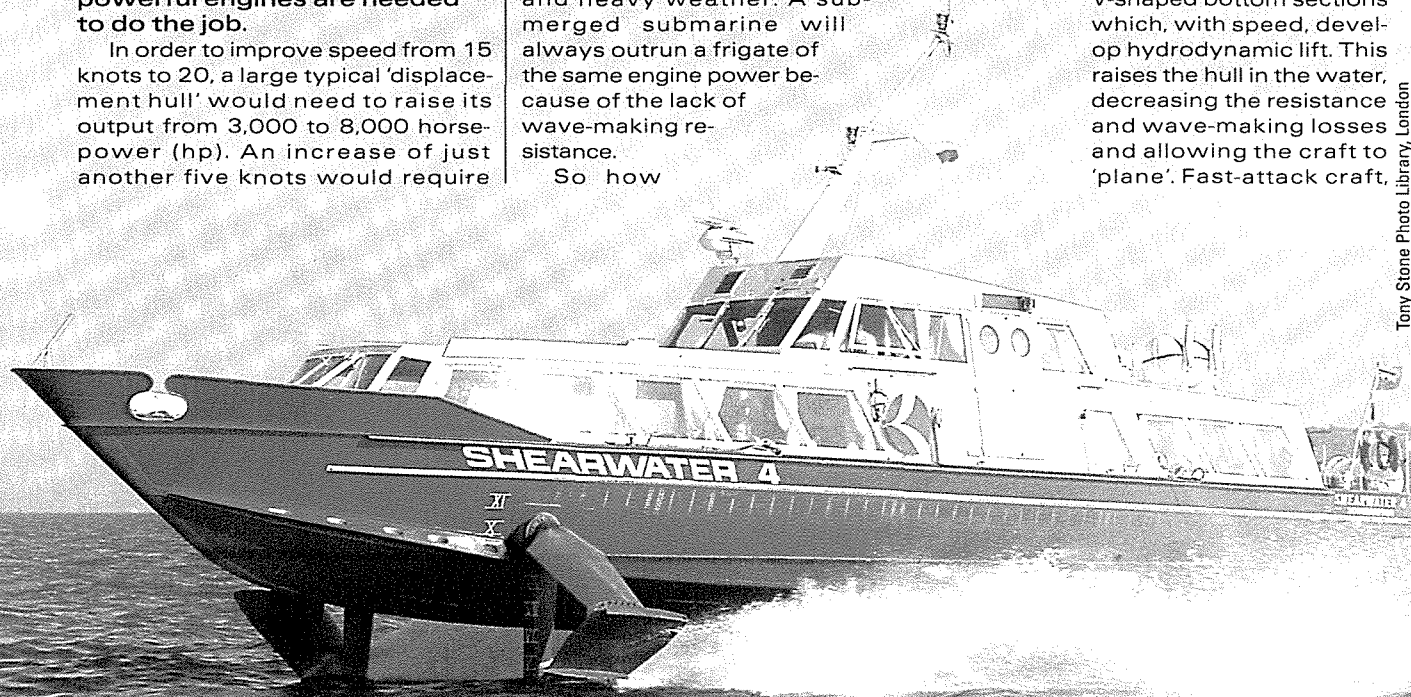
'Skin friction' between hull and water is moderate and predictable compared with 'wave-making resistance', which increases rapidly with speed and heavy weather. A submerged submarine will always outrun a frigate of the same engine power because of the lack of wave-making resistance.

So how

is speed to be achieved economically? Because wavemaking as well as frictional resistance results from interaction between hull and water, the obvious step is to reduce or eliminate the area of contact between them.

Still the simplest method is to give a hull flat, V-shaped bottom sections which, with speed, develop hydrodynamic lift. This raises the hull in the water, decreasing the resistance and wave-making losses and allowing the craft to 'plane'. Fast-attack craft,

Tony Stone Photo Library, London



A hydrofoil has underwater 'wings' that lift the vessel's hull in the same way as an aircraft's wings lift a plane. To ensure a smooth ride in rough seas, sensors feed signals into a computer (left) which incline the aircraft-style flaps on the submerged foils at the correct angle.

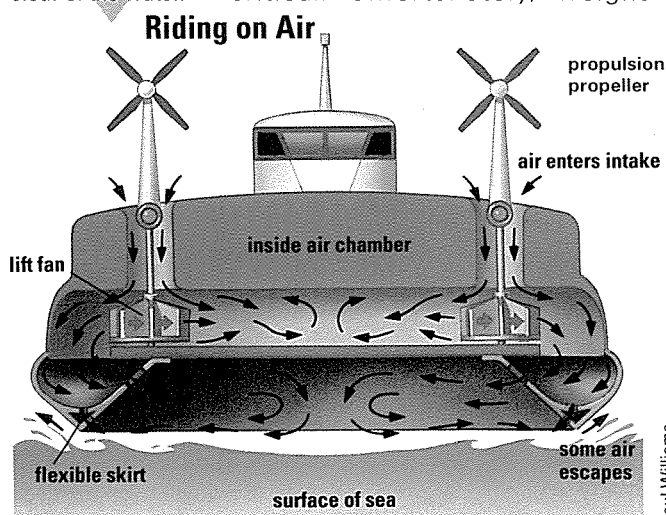




Hovercraft travel on a cushion of air. This is contained by a flexible rubber skirt to give it a smooth ride. A little of the air escapes around the edges, lifting the craft clear of the water.

method, the water jet exhausts neatly in the centre of the large foil supporting the craft's after end. Jetfoils can carry over 300 passengers in aircraft-style seating at a continuous 45 knots (85 km/h).

One drawback with hydrofoils is their limited size because, like aircraft, they rely on lift and are thus weight-critical. Unfortunately, weight



Paul Williams

Modern armies use high-speed ship-to-shore amphibious landing craft to transport military personnel, equipment and weapons systems.

just 30 metres in length, can thus move at up to 54 knots – that's over 100 km/h.

It requires very careful design, however, to prevent such craft from slamming hard in a seaway, causing material damage and fatigue. Hydrofoils can reduce the problem. These are attached to struts beneath the hull, and work much like submerged aircraft wings to lift it completely clear of the water.

Taking off

Since this process is very similar to flying, the terminology used is also alike. For instance, the craft 'takes off' from being 'hullborne' to 'foilborne'. It then 'flies' until speed is reduced, al-

lowing the hull to 'touch down' to float conventionally.

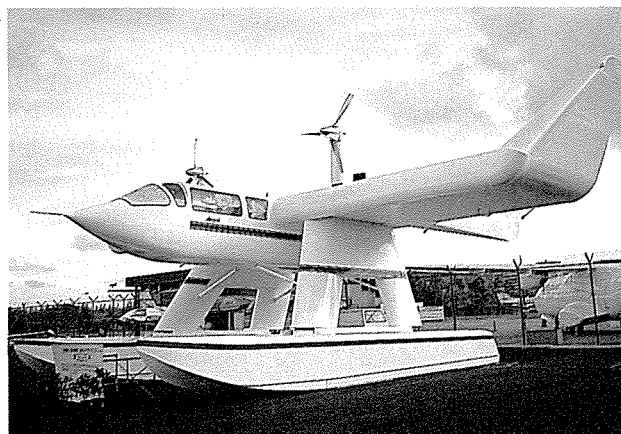
While 'flying', a hydrofoil creates minimum disturbance but, in longer waves, it will follow the wave profile, which can still cause a bumpy ride. For this reason, sensors are installed to record accelerations and surface clearance, their signals being fed into a computer which continuously controls aircraft-style flaps on the foils. The result is a smooth ride in waves up to four metres high.

Jetfoils

In flight, a hydrofoil's keel may be a couple of metres above the surface of the water, which makes propulsion by conventional shafts and propellers very difficult. This is why the 'water jet' has become popular. With this

'WIG' EFFECT CRAFT

Taking the principle of a hovercraft one stage further is the WIG (Wing-in-Ground Effect Craft), which often looks like a stubby-winged aircraft. It takes off from a flat surface, usually water, but, once airborne, redirects some engine thrust downwards. This creates a rolling air bubble beneath it, providing lift for only a low expenditure of energy. Design studies have projected WIGs of considerable size, carrying hundreds of passengers at up to 140 knots at heights of over 100 metres. Incapable of free flight, a WIG can be licenced to operate more cheaply as a boat.



E. Nevill/TRH Pictures

The weight of water displaced by every floating vessel – cruise liner, supertanker, frigate or yacht – is equal to the weight of the vessel and its contents.

increases as the cube of the dimensions and lift only as the square. In contrast, the hovercraft actually increases its efficiency with size but weight is still important as, in forward flight, up to 86 per cent of developed power may be used for lift and only 14 per cent for propulsion.

Hovercraft with fully flexible skirts are termed Air Cushion Vehicles (ACVs) and are fully amphibious, which means that they can move from water to ice, marsh, beach or rapids with equal facility. Heavy seas, however, can rapidly degrade their performance.

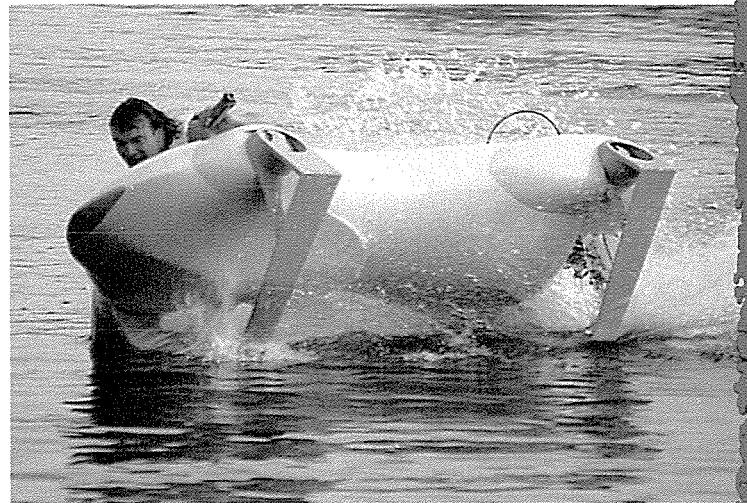


Military uses

Among the most enthusiastic of the ACV users is the US Marine Corps. Without exposing an expensive amphibious assault ship to the enemy ashore, her Air Cushion Landing Craft (LCAC) can run a 60-tonne main battle

The Flying Frog is a one-man hydrofoil. Its 15-horsepower outboard motor sends it skimming across the waves at an altitude of 60 cm and a speed of 64 km/h.

The catamaran Jet Services V set a new trans-atlantic sailboat record, making the crossing in 7 days, 6 hours and 30 minutes despite problems with the sail (below left).



Rex Features

tank ashore at 40 knots and deposit it, if required, a considerable distance inland. In calm conditions, a lightly loaded ACV is capable of 70 knots (130 km/h).



Buoyant sidewall

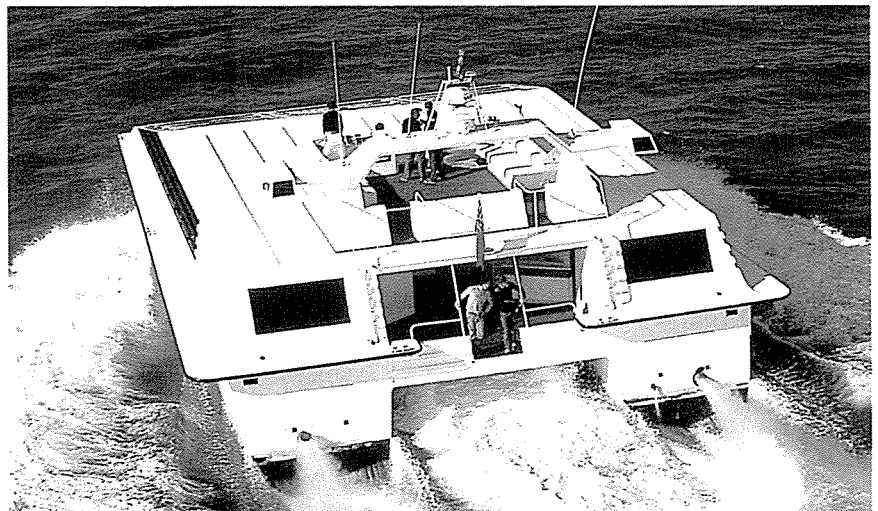
Other types of hovercraft have rigid sidewalls. Although this makes them less amphibious, they have an advantage in that the buoyant sidewalls can accommodate their machinery, so that quieter and cheaper marine engines can be used. A 4,000-tonne craft of this type, though possibly requiring water jet propulsion, could

The ultra-hi-tech bridge of a luxury catamaran – the ultimate in millionaires' playthings, this huge ocean-going craft can be crewed by just one person.



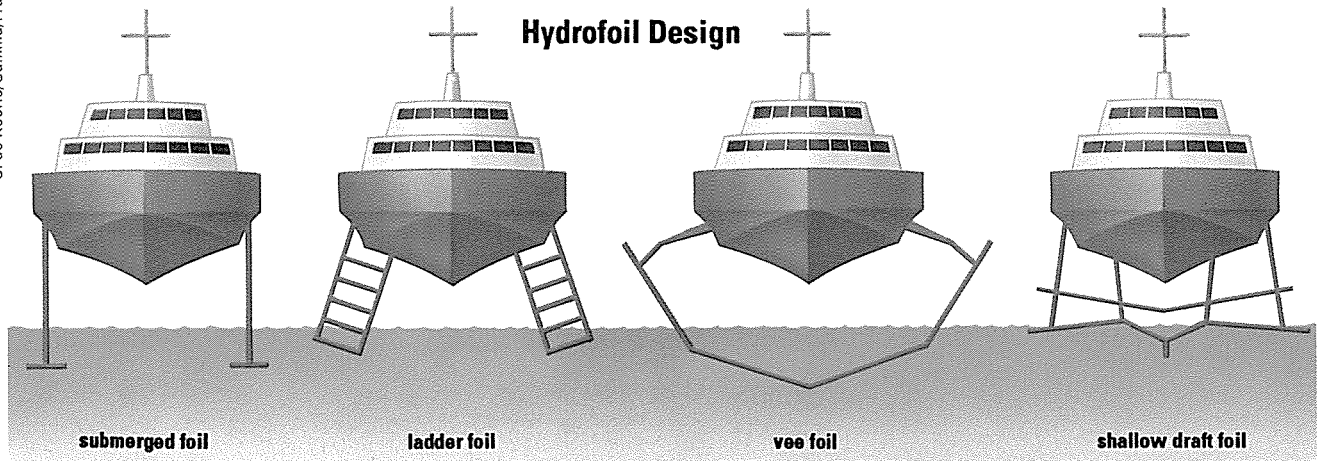
G. de Keerle/Gamma/Frank Spooner Pictures

A submerged foil gives more lift at higher speeds. To compensate, the ladder and vee foils put more foil area in the water at lower speeds.



Jim Selby/Rex Features

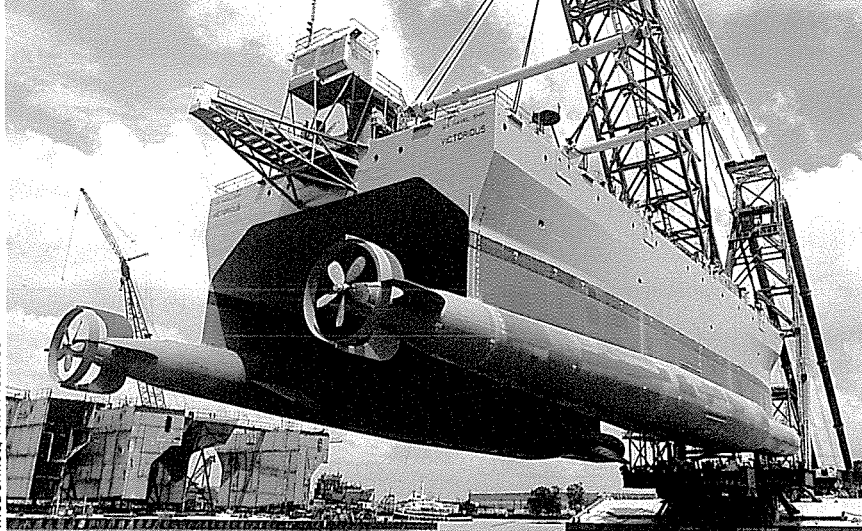
Hydrofoil Design



G. de Keerle/Gamma/Frank Spooner Pictures

Paul Williams





is the secret of the Wave-piercing Catamaran. Exciting designs of these have been produced — particularly by the Australian International Catamaran company (INCAT). Called SeaCats, their slim supporting hulls, are little affected by the waves.

Hoverspeed

The SeaCat *Hoverspeed Great Britain*, which makes the Portsmouth-Cherbourg crossing in just 160 minutes, crossed the Atlantic in June 1990 in just three days, seven hours, 25 minutes and 14 seconds.

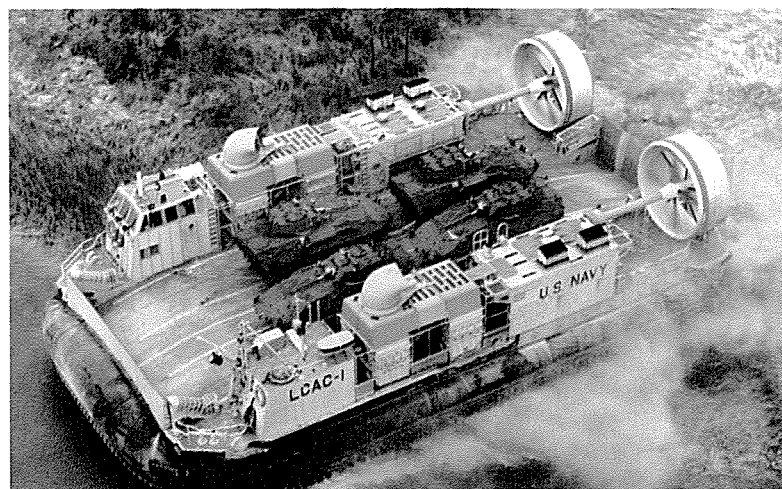
High-speed, medium-sized ferries of this type have tremendous poten-

SPEEDY MONOHULLS

In 1986, Richard Branson's *Challenger II* put deep-vee monohulls back on the map, covering the North Atlantic Blue Riband course between America and Britain in three days, eight hours, 31 minutes, 35 seconds. Although his boat was only 22 metres in length, it beat the previous record, set by the 53,000-tonne liner *United States*, by over two hours.

This feat provoked the American Tom Gentry to build the 33.7 metre *Gentry*

The USNS Victorious — the latest in US Navy SWATHs — is used to survey the seas. It maps the ocean floor, looking for places that enemy submarines could hide.



The hovercraft is the perfect assault landing vehicle. This one carries tanks and armoured personnel carriers for the US Marines.



Eagle. While slower than Branson's 55-knot craft, the *Eagle's* greater size enabled her, in the following year, to maintain 48 knots across the Atlantic, slashing the record again, this time by a further 18 hours and 23 minutes.

In 1992 the *Destriero* completed the crossing in 58 hours 34 minutes.

cruise at 80 knots (148 km/h) on 140,000 hp, probably only half the power required for a conventional monohull of similar performance.

Twin hull

In practice, a sidewall hovercraft such as this is a catamaran, supported by an air cushion. The generous deck space provided by the catamaran concept, combined with something of the steady ride offered by the SWATH (Small Waterplane Area, Twin Hull),

tial on short sea crossings such as those on the Baltic or the Mediterranean, or between the Japanese islands.

SeaCats have joined the particularly ferocious competition on the heavily used English Channel routes now the tunnel has been completed. To meet this sort of challenge INCAT is already building a 110-metre wave-piercing catamaran powered by Rolls-Royce Spey gas turbines. Capable of 40 knots and more, these ferries are designed to travel down the fast lane!

Just amazing!

BLOW IT!

THE INVENTOR CHRISTOPHER COCKERELL FIRST DEMONSTRATED THE PRINCIPLE OF THE HOVERCRAFT USING A VACUUM CLEANER AND TIN CANS.



Fast coastal patrol boats are vital to the US Coast Guard, in their struggle to keep drugs out of America. Boats like this one intercepted 6.5 tonnes of cocaine and 115 tonnes of marijuana in 1988.

●  MULTI-VALVE HEADS

 SKID-FREE BRAKING

 ALUMINIUM FRAMES

ON YOUR BIKE

THE STURDY ENGINE REVS.

The clutch is open, ready to drop. The light flashes green. The air smells of rubber. Man and bike accelerate down the smooth tarmac to a speed approaching 290km/h.

This scene is not confined to the race track. It could happen now, where speed limits allow, out on the street with one of the new generation of motorbikes. They are the first cousins of the all-out speed machines found on the race track, the test bed for motorcycle design.

But top speed alone is not the be all and end all of the motorbike. To use all the engine's power effectively, the frame, running gear and brakes have to be up to scratch.

Street legal

The power to propel street-legal bikes at this speed comes from dramatic development of engine technology. In four stroke engines, long gone are the days when there was just one valve in the cylinder head to let the fuel-air mix into the combustion chamber and one to let the burnt gases out.

The norm today on performance bikes is four valves per cylinder driven by double overhead camshafts. This, combined with the shape of the cylinder head and the top of the piston, gets the right amount of mix in and out of the cylinder quickly and swirls the gases around so they are mixed



Advances made in the design of motorbikes are...
...streamlined bikes are...
...streamlined

Photo: Tony Stone Photo Library, London

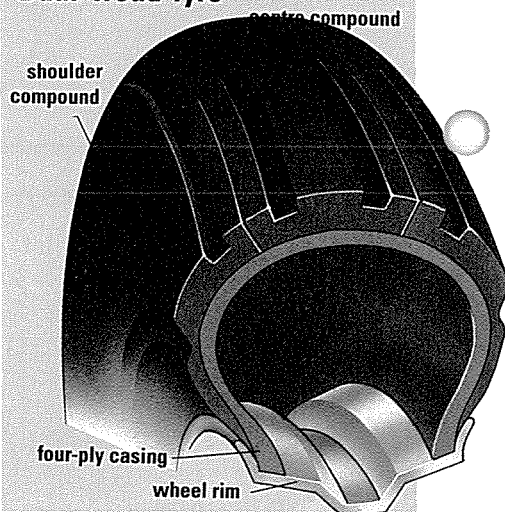




The rounded shoulders of a motorbike tyre provide grip for cornering, but most mileage is done on the middle section that gets most wear. So different compounds are used to give even wear.

The frames of superbikes are welded by the latest generation of robots. Aluminium alloy is taking over from steel in bike frames (below). Box section frame members make the chassis rigid.

Dual-Tread Tyre



Mark Franklin

Yamaha FZR1000 suck air into the engine and send it down straight, short tubes to the inlet valves, adding petrol as the air passes.

Honda have gone one step further and following racing successes have introduced engines with elliptical pistons and eight valves. The advances comes as a result of studies of gas flow and combustion flame-front characteristics during engine operation made using ultra-high speed photography through windows in the combustion chamber walls.

Electronic ignition

All modern bike engines feature electronic ignition. This gives improved timing accuracy and a higher spark intensity necessary to ignite the comparatively weak fuel-air mixture needed for today's environmentally sympathetic bikes. They run hotter and more reliably thanks to improved metallurgy. This means that more bikes are now water cooled. Some even have water-cooled oil coolers.

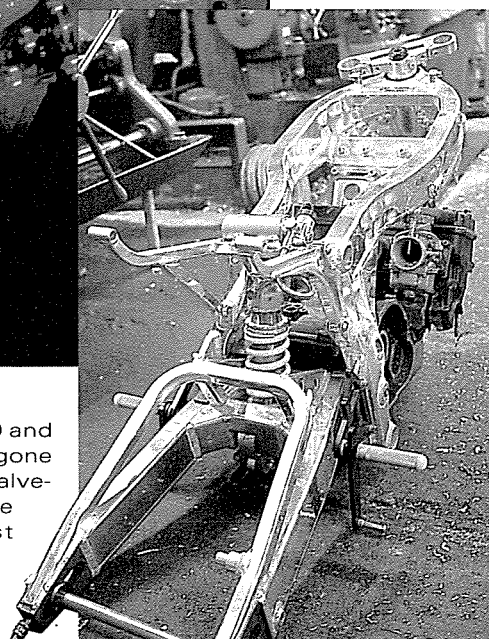
well and burn smoothly and fully.

Yamaha, with their FZR1000 and OW-01 FZR750R models, have gone one step further and have five valve-per-cylinder engines; with three inlet valves and two exhaust valves for even better engine breathing. Some Yamaha models also feature a new microchip-controlled exhaust tuning system called Exhaust Ultimate Power Valve or EXUP. In conventional motorcycle exhaust design the exhaust is designed to be most efficient and give most power when the engine is working at just a small rev range. As the valves slam open and shut and the gases rush down the header tubes they set up 'resonance' that speeds the gas flow for a certain length and diameter of the tube.

Tuned exhaust

This 'resonance' only assists the engine over a relatively narrow range of revs. But by adding a servomotor controlled valve between the header pipes and the tube to the silencer the pipe system is tuned, depending on the speed of the engine.

At the other end of the engine the downdraught carburetors of the



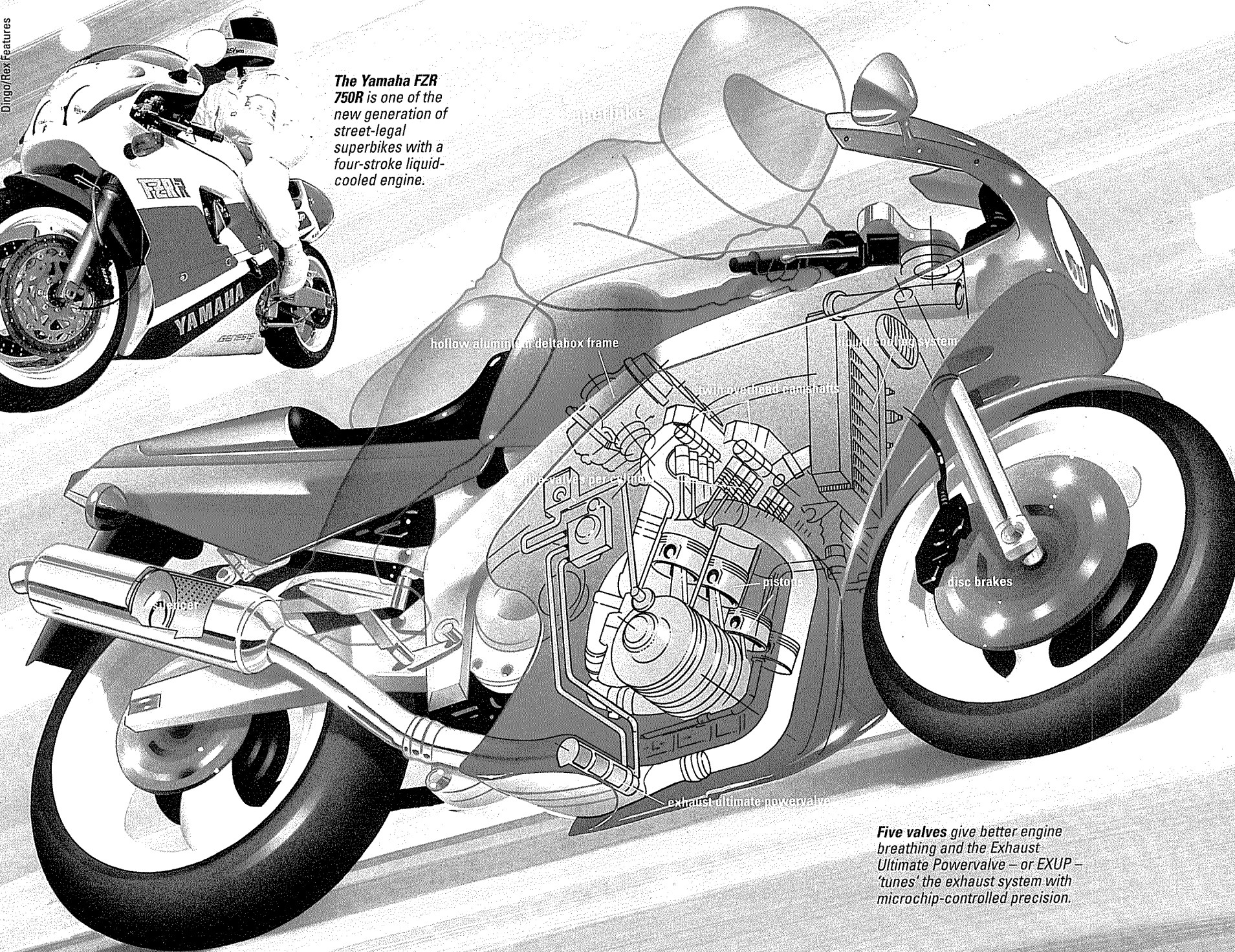
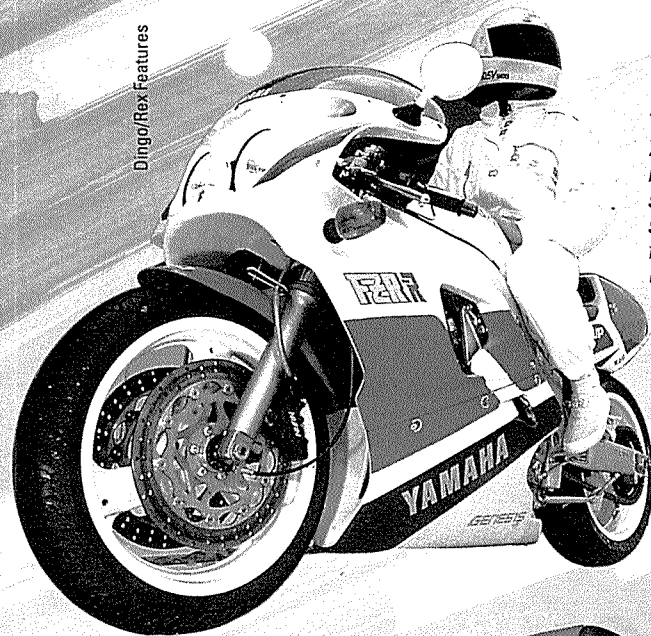
Performance Bikes

Motocross tests bikes for their ability to handle tough terrain. Sidecar events are particularly exciting, with the passenger shifting his body for balance.



Leo Mason/Split Second

The Yamaha FZR 750R is one of the new generation of street-legal superbikes with a four-stroke liquid-cooled engine.



hollow aluminum deltabox frame

twin overhead camshafts

five valves per cylinder

pistons

disc brakes

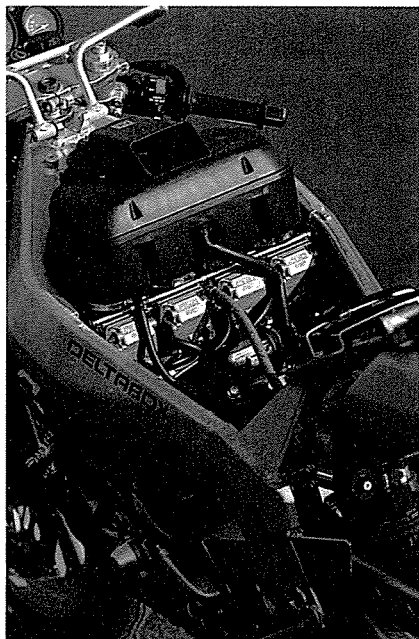
exhaust-ultimate powervalue

Five valves give better engine breathing and the Exhaust Ultimate Powervalue – or EXUP – ‘tunes’ the exhaust system with microchip-controlled precision.



Many motorcycles still rely on tube steel cradle frames. But the most advanced sports bikes now employ ultra-lightweight box section 'wraparound' race-developed aluminium frame for unparalleled torsional stiffness. They use superior suspension systems using metal and air springs, partnered by hydraulic damping, often assisted by inert gas to

Quad racing is a new fad among motorsports fans. The strange four-wheeled motorbikes are raced across sand dunes and other rough terrain.



Performance Bikes

inhibit fluid frothing. Breaking with tradition, Suzuki, on their GSX-R1100 and GSX-R750 models, have turned the front forks of the motorcycles upside down to reduce unsprung weight in the increasingly heavy dampers.

The upper tubes are connected via clamps to the steering head bearings which give contact with the main

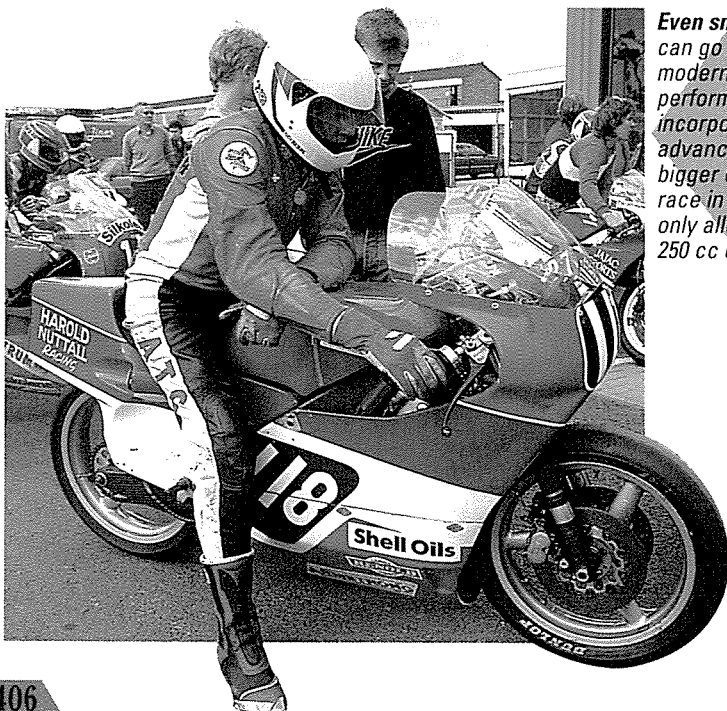
To improve fuel efficiency, performance bikes use banks of carburetors to feed each cylinder with its petrol-air mixture independently.

frame. The fork stanchions hold the front wheel axle. This follows racing practice and development. Both the front and rear suspension are adjustable for spring pre-load and separately for rebound and compression damping.

Many large bikes have single rear suspension spring and damper units

mounted at the rear of the engine with remote damping reservoirs. Wheels are large and squat so large tyres can be fitted for maximum grip for cornering and for acceleration. Many bikes now also feature radial tyres, and really large bikes have very wide rims at 14 cm to take the fat tyres.

Anti-lock Brake System - ABS - is now available on the Yamaha FJ1200A. Twin electronic control units independently monitor wheel lock-up on changing road surfaces. This enables the tyres to deliver their full performance.



Performance Bikes

Even small bikes can go fast. These modern performance bikes incorporate all the advances of their bigger cousins but race in a class that only allows a 250 cc engine.

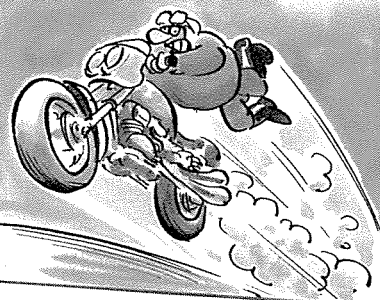


Tony Stone Photo Library, London

Just amazing!

HANGING ON

IF TOP SPEEDS CONTINUE RISING AT THE CURRENT RATE, BY THE YEAR 2010 MOTORBIKES WILL BE CAPABLE OF 400 KM/H.



Paul Raymond





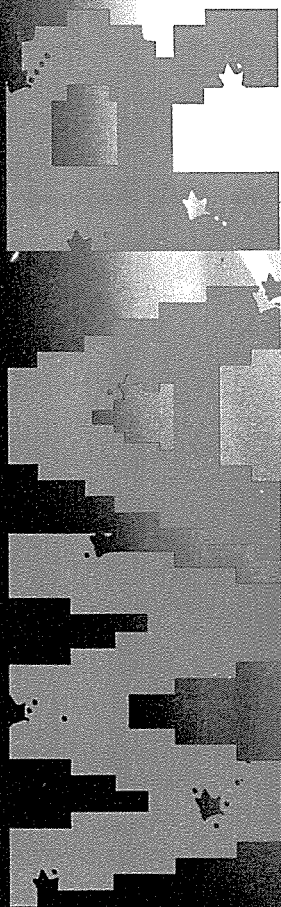
MAD



NUCLEAR WINTER



NON-PROLIFERATION



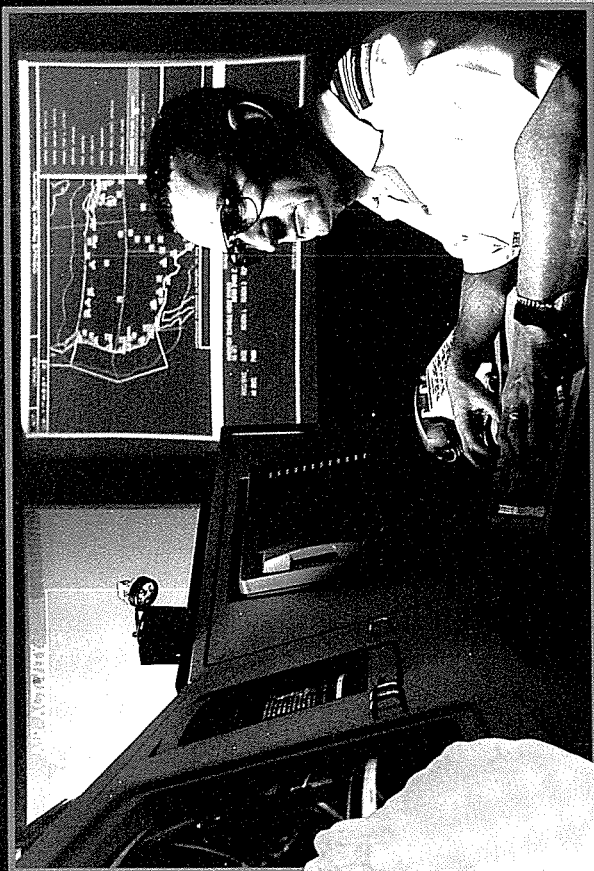
NUCLEAR WAR CAN HAPPEN, despite the end of the cold war. Although Russia and the United States are cutting back their nuclear arsenals, both intend to retain sufficient nuclear weapons to deter the other side from launching a nuclear strike.

The superpowers are now moving to a strategy of what is known as minimal deterrence. In other words, each will retain just enough nuclear warheads to ensure unacceptable damage on the enemy's countries, even after the other has launched a surprise attack.

Second strike

Mutual deterrence can be maintained by assured destruction — a war in which each side has nuclear arsenals that works if each side's nuclear arsenal is wiped out. This would include nuclear systems that would not be wiped out in a first attack. This 'second strike' capability is primarily provided by submarine-launched ballistic missiles (SLBMs). These are fired by nuclear submarines hiding deep in the ocean and virtually undetectable. Land-based intercontinental ballistic missiles (ICBMs) and even air-launched cruise missiles (ALCMs) are more vulnerable.

The idea behind this strategy is to



H. Apstein/Guy/Gamma/Trank Spooner Pictures

The mushroom cloud has become the poignant symbol of nuclear holocaust. This one was caused by the test of the first hydrogen bomb.

Air units — the North American Air Defense Command — keep a constant watch for incoming bombers and missiles.

detonation of even a fairly small number of nuclear warheads would throw up so much debris in to the atmosphere that the light of the sun could be blocked out. This would plunge the Earth into permanent semi-darkness and freezing temperatures making life difficult, if not impossible. It has not yet been established how long such an adverse period would last.

There is no defence against nuclear attack. The Strategic Defense

Initiative — or Star Wars programme — that aimed to use killer satellites to destroy nuclear missiles in flight has been quietly phased out. Few people were convinced that it could work.



Civil defence

Most civil defence programmes against the possibility of nuclear attack are also being abandoned. Their effectiveness was always in doubt. It was also argued that the very exis-

U.S. Dept of Energy/Science Photo Library



tence of a civil defence programme – building underground shelters or making plans to evacuate cities – is in itself provocative.

With nuclear weapons around, there is always a danger of an acci-

result of a faulty bomb release mechanism. It did not explode.

Nuclear weapons are increasingly being controlled by computers. These can go wrong. In January 1984, a computer error in a control console at

SURVIVABILITY?

In the worst scenario, nuclear war would initially kill 1,600 million people and injure 930 million more – 86 per cent of the population of the industrialized nations and some 46 per cent of Third World. There would be so many dead it would be impossible to bury them. The cities would be full of rotting corpses. The water and sewage systems would be destroyed. Diseases would spread rapidly. The remaining doctors would be overwhelmed. Drugs would run out. There would be no electricity to power the machinery in hospitals – and no fuel to keep the ill and dying warm.

Industrial and agricultural production would virtually halt. There would be economic chaos and mass starvation. In six months over three quarters of the world's population would be dead.

USAF/TRH Pictures



dent. Although there has never been an accidental detonation of a nuclear weapon, there have been several accidents involving missiles and bombs.

Figures released by the US Department of Defense in 1980 claimed that there had been fewer than 40 accidents involving nuclear weapons. However, a survey conducted by the Stockholm International Peace Research Institute in 1977 found evidence of more than 130 accidents all together.



Dropped by accident

Nuclear bombers have crashed at Palomares in Spain and at Thule in Greenland. These incidents smashed the nuclear weapons they were carrying and spread their plutonium cores over a wide area. In another accident near Kirkland Air Force Base in the United States, a 10-megaton nuclear bomb was dropped by accident as a

An American B52 bomber carrying its deadly load – air-launched cruise missiles with nuclear warheads targeted on the Soviet Union.

The US Air Force Strategic Air Command co-ordinates American nuclear missile launches in the event of a Soviet attack.



USAF/TRH Pictures

Warren Air Force Base in Wyoming made it look as if a nuclear missile was about to launch itself. Although the US Air Force still insists that there was no danger, a safety crew did take the precaution of parking an ar-

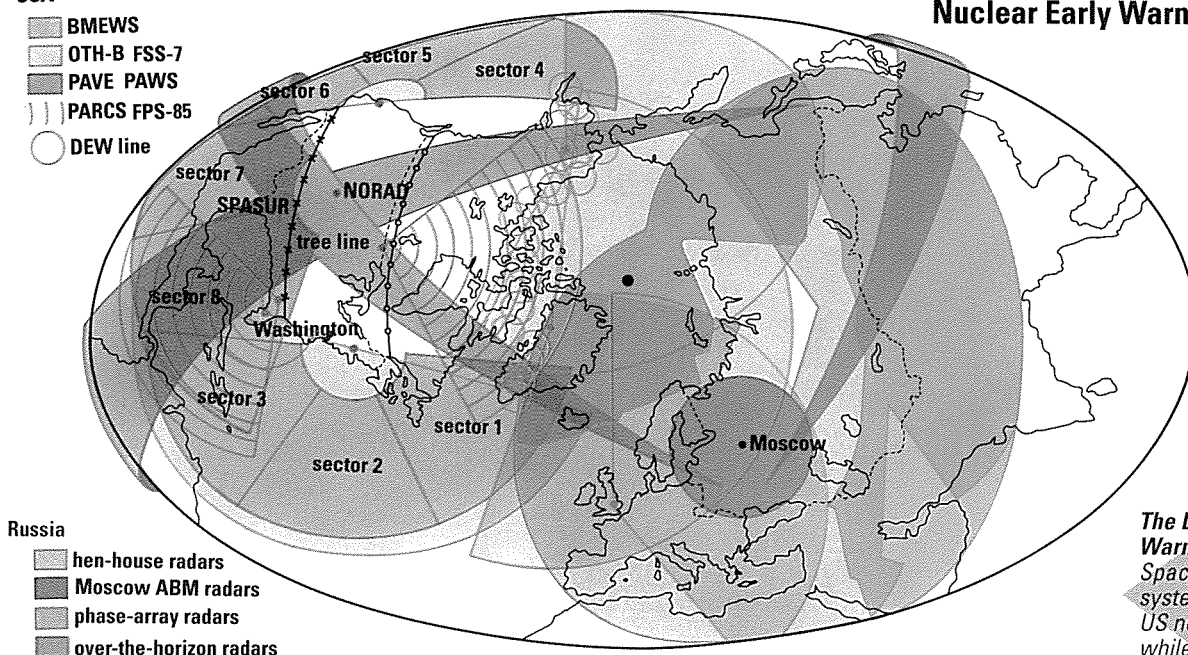
moured car across the top of the silo to prevent the launch of the missile.

Another problem is finding people stable enough to be put in charge of nuclear weapons. There is always a danger that one of the people respon-

USA

- BMEWS
- OTH-B FSS-7
- PAVE PAWS
- || PARCS FPS-85
- DEW line

Nuclear Early Warning



Paul Williams

Russia

- hen-house radars
- Moscow ABM radars
- phase-array radars
- over-the-horizon radars

The Distant Early Warning line and Space Surveillance system protects the US north and south, while anti-ballistic missile radars ring Moscow.





USAF/DOD

The launch sequence of an American 'Peacekeeper' missile. This uses a 'cold' launch system. A gas generator blasts the missile 30 metres in the air before the rocket motor ignites.

sible for launching nuclear missiles will become mentally ill or start abusing drugs. The US programme that screens for unstable individuals removes about five per cent of staff – around 5,000 people – from nuclear weapons duties every year.

Permissive Action Links

All US, British and French nuclear weapons are controlled by what are termed Permissive Action Links or PALs. The technology is a closely guarded secret but basically PALs are electronic devices which prevent the launching of a nuclear missile or the arming of a nuclear bomb unless a series of electronic signals are transmitted from more than one

Terrorists

The risk of nuclear weapons falling into irresponsible hands is real. If terrorists got hold of them, the consequences would be catastrophic. And there is always a danger that nuclear weapons will fall into the hands of smaller nations which have militant or unstable leaders.

So far, Russia and other states of the former USSR the US, the UK, France and the People's Republic of China admit to having nuclear weapons. But there are also a number



of other countries whose nuclear status is less clear.

Israel is thought to be continuing to develop its nuclear capability. It is believed to be expanding into both large thermonuclear strategic weapons as a deterrent as well as a

Just amazing!

OVERKILL

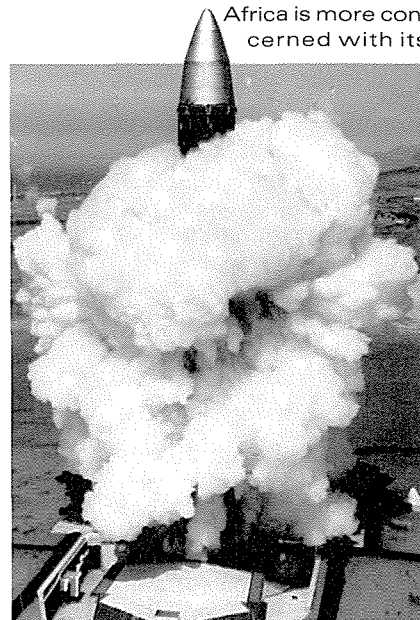
THE SUPERPOWERS' NUCLEAR STOCKPILE CONTAINS THE EQUIVALENT OF THREE TONNES OF HIGH EXPLOSIVE FOR EVERY MAN, WOMAN AND CHILD ON EARTH.



Paul Raymond

wide range of low-yield tactical nuclear weapons for use on the battlefield. It is also developing ballistic missiles to keep pace with other countries in the Middle East such as Iraq, Egypt, Syria and Iran who are already equipped with ballistic missiles.

It is suspected that South Africa has nuclear weapons. But South Africa is more concerned with its



NATO troops performing decontamination drill. Wearing NBC – nuclear, biological, chemical – suits, the men hose down vehicles that might be carrying contaminants.



source. Russian technology is not so sophisticated but they do operate various 'dual key' arrangements to ensure that no unauthorized launchings can take place.

The Kurds of Halabja were the victims of chemical warfare. They were gassed by Iraq to suppress calls for an independent Kurdistan.



SIPA/Rex Features



PROSPECTS OF PEACE



Photo Associates/Rex Features

Nuclear weapons have kept the peace in Europe for the past 45 years. And globally just 17 million people have been killed in wars since 1945. Between 1914 and 1945, when the first atomic bomb was dropped, 75 million people were killed in wars and their aftermath. The recent thawing in the cold war has allowed the numbers of nuclear weapons to be reduced and made nuclear confrontation less likely in the future.

internal situation and nuclear weapons have a lower priority than they did ten years ago.



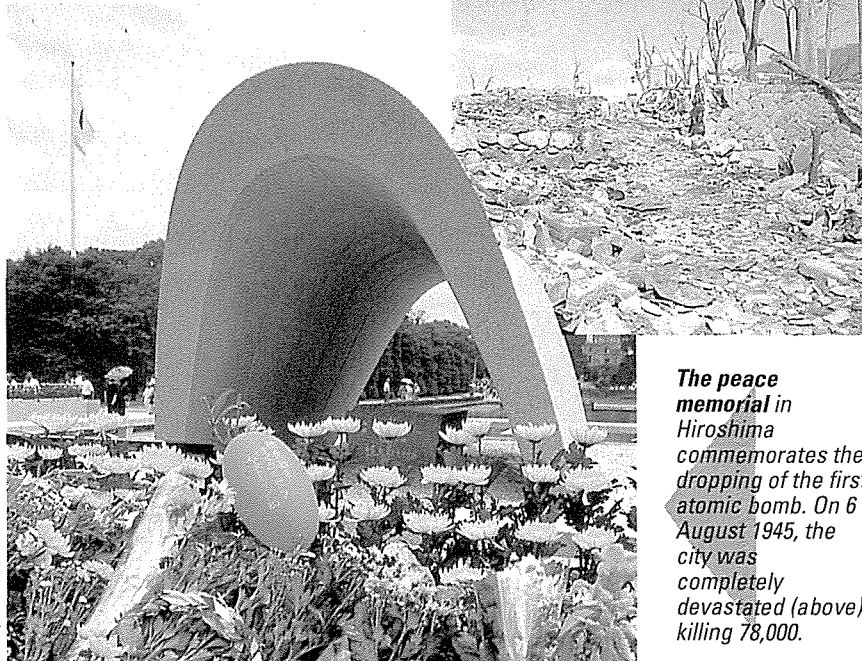
Weapons in Asia

India has exploded a nuclear device and Pakistan is thought to be on the verge of developing a nuclear weapon. Both India and Pakistan are also developing medium range ballistic missiles and the possibility of a nuclear war between these hostile

neighbours cannot be ruled out.

In Latin America, Argentina and Brazil appear to have slowed their nuclear weapons programmes, probably due to lack of money. Other countries who are thought to have begun nuclear weapons programmes are North Korea, Iran and Iraq.

It is perhaps surprising that the spread of nuclear weapons is not



SIPA/Rex Features

The peace memorial in Hiroshima commemorates the dropping of the first atomic bomb. On 6 August 1945, the city was completely devastated (above), killing 78,000.

USMC/TRH Pictures

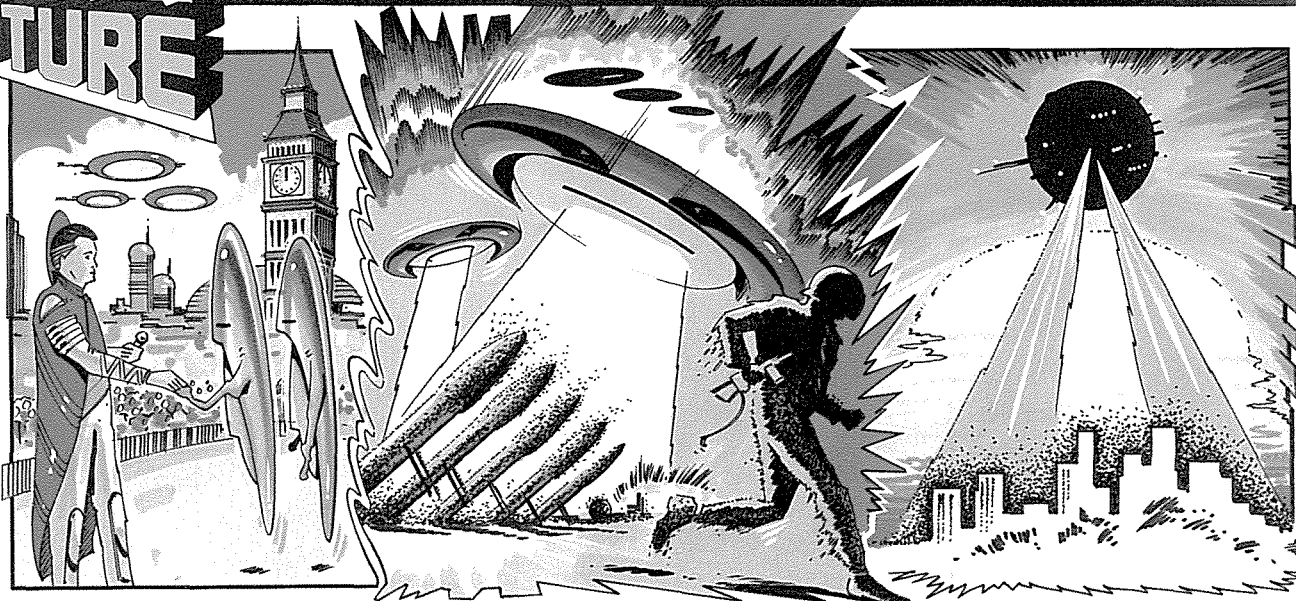
worse than it is. This is perhaps in part due to the Non-Proliferation Treaty. The future of the treaty, to which 139 states are signatories, was decided at a conference in 1995 at which time it had been in operation for 27 years. The agreement was confirmed.

However, many countries in unsta-

ble, war-prone regions are not party to the Non-Proliferation Treaty - examples include Israel, Pakistan and India. So the problem of how to prevent the spread of nuclear weapons beyond the acknowledged nuclear powers still remains only partly solved.

INTO THE FUTURE

ALIEN ATTACK



▲ If aliens arrive on Earth, they must come from an extremely advanced civilization. However, there is no reason to believe that they would be aggressive.

▲ But if they are warlike, they will - no doubt - have invented terrible weapons of mass destruction. Our chemical, biological and nuclear arms would look puny to them.

▲ It is likely that an alien civilization would have come up with laser or direct energy weapons - weapons against which we would have no defence.

Joe Lawrence

